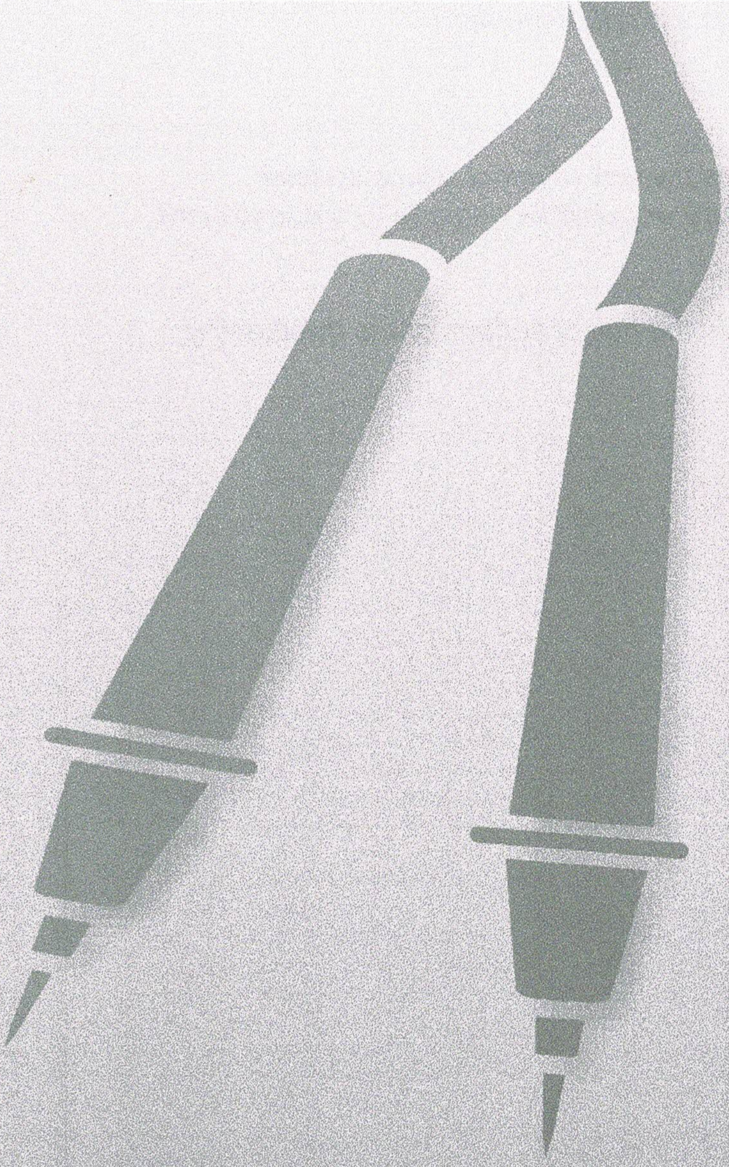
AUTO-TECH MASTERCLASS

Training for Master Technicians



- CAN BUS
  Introduction to Diagnosis
- VVT Fault Diagnosis
- Suspension,
  Advanced Fault Diagnosis
- Evaporative Emission Systems
- Exhaust Gas Recirculation
  (EGR) Diagnosis
- Advanced Safety Systems

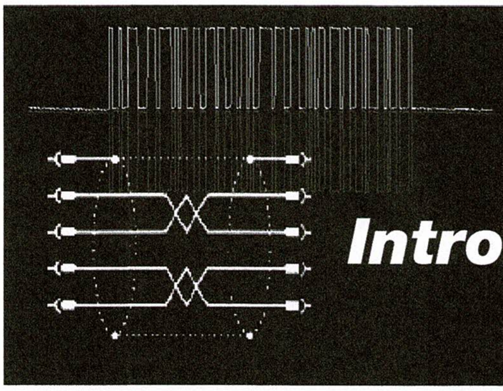
2017.1

DIAGNOSING
CAN, VVT, EGR & MORE

LOOK FOR THESE SYMBOLS THROUGHOUT THE MANUAL

ⓘ	*Note:*	*Indicates a point of interest*
⚠	*Caution:*	*Indicates the risk of minor injury, special procedure or possible damage to a component*
⚠	*WARNING:*	*Indicates the risk of serious or life threatening injury*

© Copyright 2017 Repco Pty Ltd. All Rights Reserved



Section i

CAN Bus Introduction to Diagnosis

CONTENTS

INTRODUCTION 4

THE NETWORK 4
Control Modules 5
Terminating Resisters 6
Wiring 6

DIAGNOSTIC CONNECTOR 7
Ground and Power circuits 8
Discretionary circuits - Part I 8
Discretionary circuits - Part II 9
Discretionary circuits - Part III 9
J1850 BUS circuits 10
ISO9141 and KWP2000 10
CAN Bus circuit 11

THE MESSAGE 12
Sending 12
Receiving 13

ACCESSING THE DATA 16

DIAGNOSTIC PROCEDURE 16

WAVEFORM EXAMPLES 28
CAN Low OPEN Circuit 29
CAN High OPEN Circuit 30
CAN High and Low OPEN Circuit 31
CAN High and Low Short Circuit 32
CAN Low SHORT to GROUND 33
Corrupted CAN message 34

INTRODUCTION

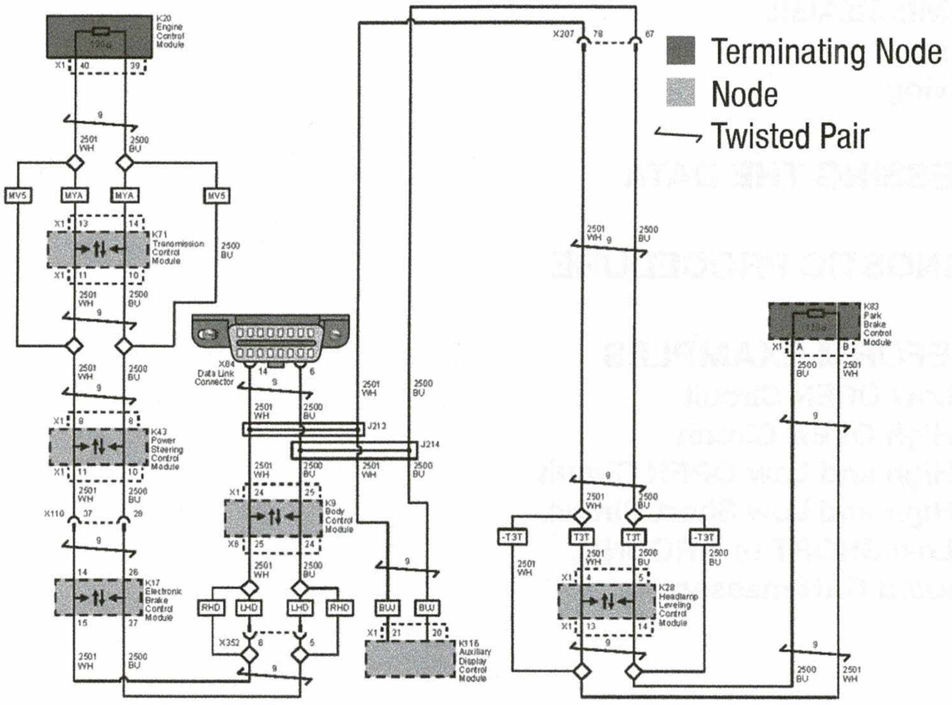
Since the full introduction of ADR79/01 (EURO III) in 2006, all vehicles in Australia and New Zealand have been required to communicate with a generic Scan Tool using a CAN Bus via the Diagnostic Connector. This therefore sets out the minimum requirement.

Quick Facts about CAN Bus:

- CAN = Controller Area Network
- Bus = is an abbreviation for Omnibus (Latin for "for all")
- Is a communication protocol
- Is used to share data between modules
- Created by Bosch in 1983
- First used by BMW in 1988
- Standard for EOBD since 2001 (Diesel 2004)
- Australian standard since ADR79/01 (EURO-III) in 2006
- Standard for OBDII from 2008

THE NETWORK

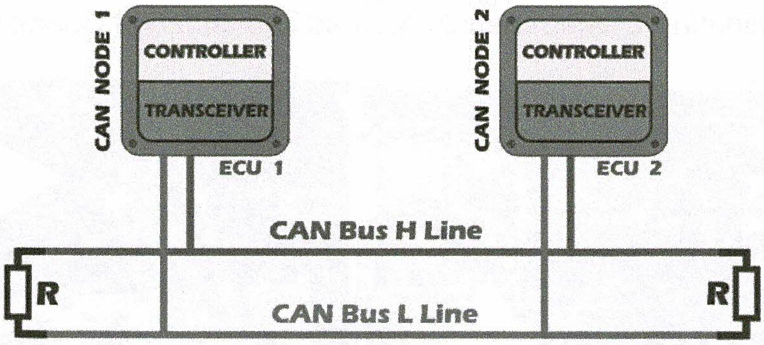
The CAN varies depending on the individual needs, this is one of the key factors of its design. It can be reduced down to the simplest system where it provides the high speed data connection between two Control Modules or expanded to provide a highly effective communication network between dozens of modules. There are limits on how many modules can use a CAN, not due to physical limitations but due to the increased traffic (signals) travelling across the network. When large numbers of modules are required to share information across a CAN, the network is broken into a collection of smaller networks with specific modules functioning on two or more networks that form gateways between the networks.


K20 Engine Control Module
120Ω
X1 40 39
9
2501 WH
2500 BU
MV5
MYA
MYA
MV5
X1 13 14
K71 Transmission Control Module
X1 11 10
X84 Data Link Connector
14 6
K43 Power Steering Control Module
X1 8 8
X1 11 10
X110 37 28
K17 Electronic Brake Control Module
14 26
15 27
J213
J214
K9 Body Control Module
X1 24 25
X8 25 24
RHD
LHD
LHD
RHD
X352 8 5
BUJ
BUJ
X1 21 20
K116 Auxiliary Display Control Module
X207 78 67
Terminating Node
Node
Twisted Pair
-T3T
T3T
T3T
-T3T
K28 Headlamp Leveling Control Module
X1 4 5
X1 13 14
K83 Park Brake Control Module
X1 A B

THE NETWORK continued...

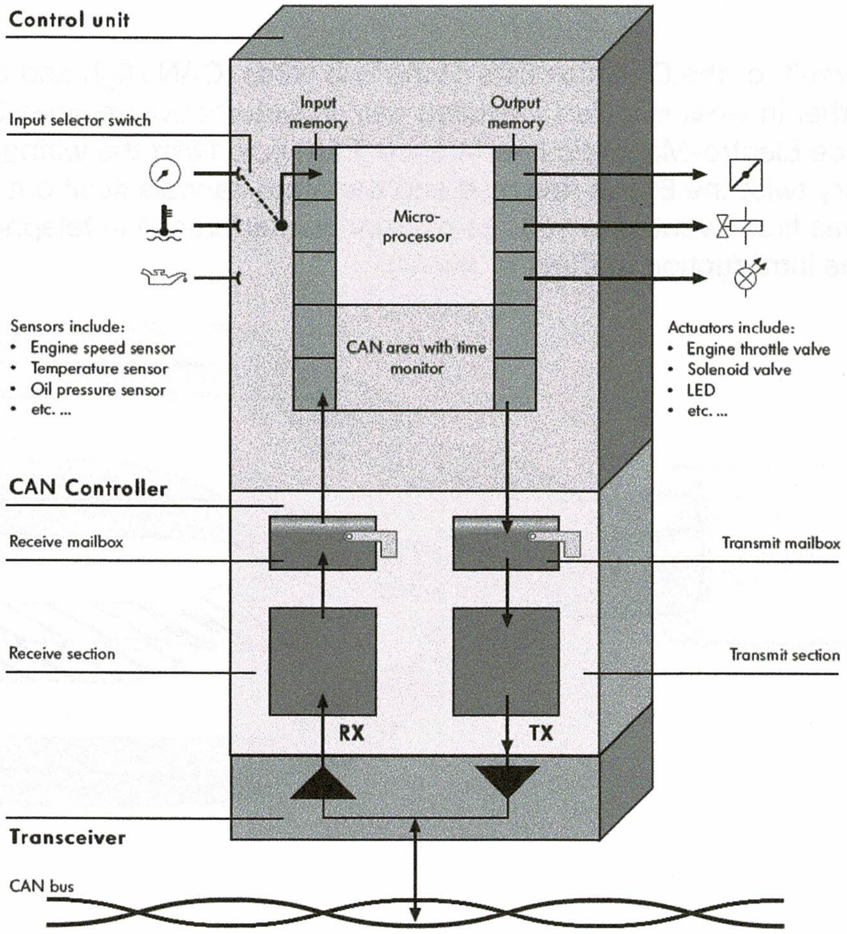
A CAN consists of:

- Control Modules (referred to as Nodes on the network)
- Terminating Resistors
- Wiring
- Diagnostic Connector


CAN NODE 1
CONTROLLER
TRANSCEIVER
ECU 1
CAN NODE 2
CONTROLLER
TRANSCEIVER
ECU 2
CAN Bus H Line
R
CAN Bus L Line
R

Control Modules

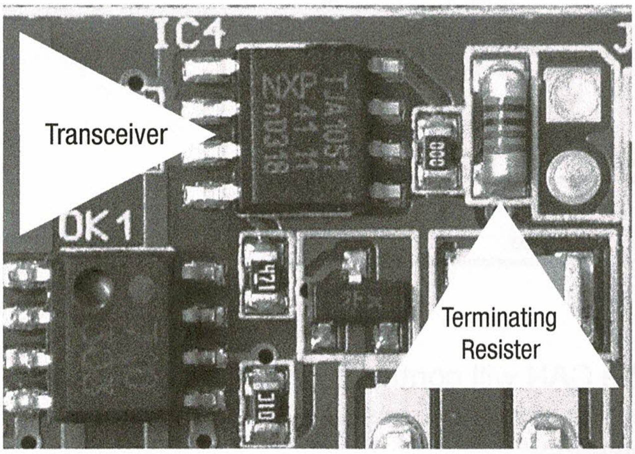
Any Control Module that is situated on the CAN will contain a circuit referred to as a Node. The Node includes the CAN Controller and the Transceiver, it is responsible for translating, sending and receiving messages.


Control unit
Input selector switch
Input memory
Output memory
Micro-processor
CAN area with time monitor
Sensors include:
• Engine speed sensor
• Temperature sensor
• Oil pressure sensor
• etc. ...
Actuators include:
• Engine throttle valve
• Solenoid valve
• LED
• etc. ...
CAN Controller
Receive mailbox
Transmit mailbox
Receive section
Transmit section
RX
TX
Transceiver
CAN bus

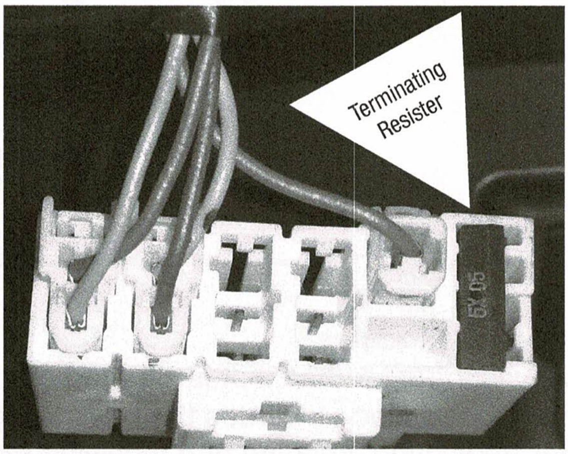
THE NETWORK continued...

Terminating Resisters

Terminating Resisters are located at the ends of a CAN, they absorb the messages to stop them from continuing along the network. The function of absorbing the message is further explained under the "The Message" topic.
The vast majority of vehicles have the Terminating Resister integrated into certain Nodes. These Nodes are called Terminating Nodes, while some vehicles have an standalone Terminating Resister usually located in a Junction Connector.



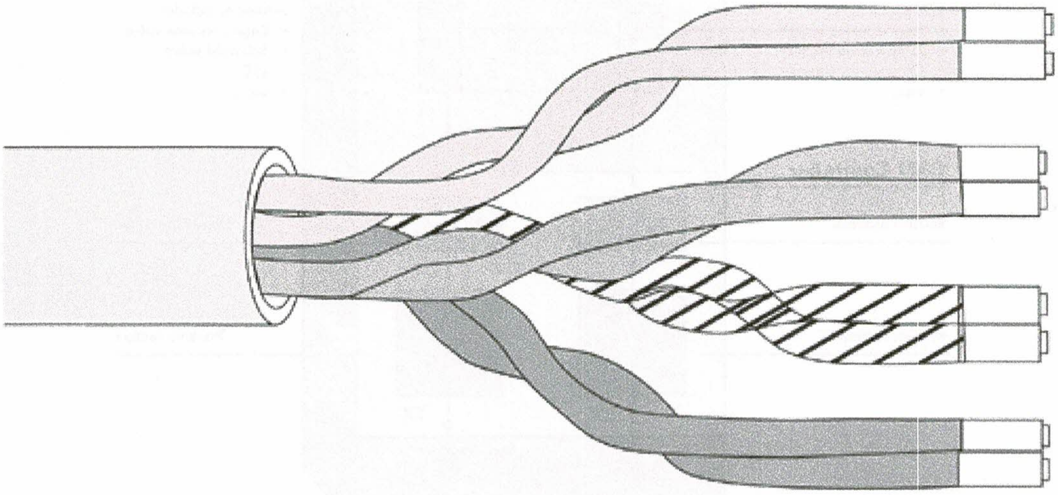
Terminating Node section of a PCB



Terminating Resister in a Junction Connector

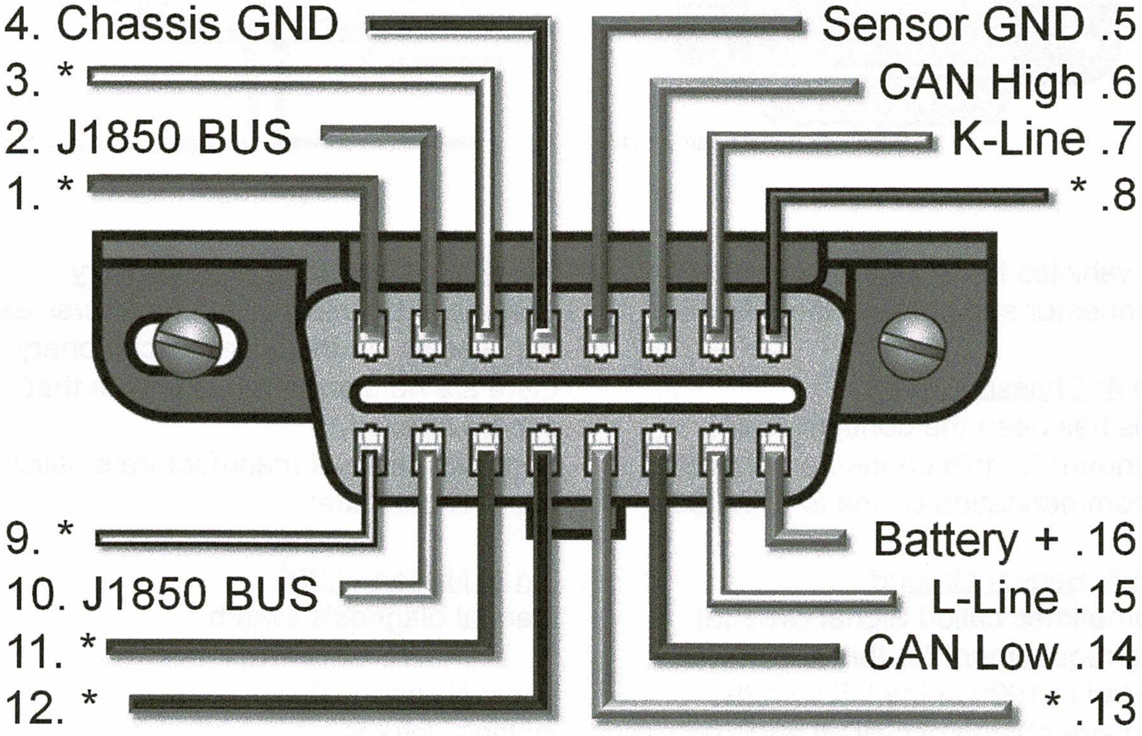
Wiring

The wiring circuit for the CAN consists of the two wires (CAN High and CAN Low) twisted together in what is called a twisted pair. In Automotive vehicles the method used to reduce Electro-Magnetic Interference (EMI) is to twist the wiring, this means that with every twist the EMI is reversed and therefore cancels itself out (Twisted Pair wiring was first invented in 1881 to overcome interference in telephone wires caused by the introduction of Electric Trams).

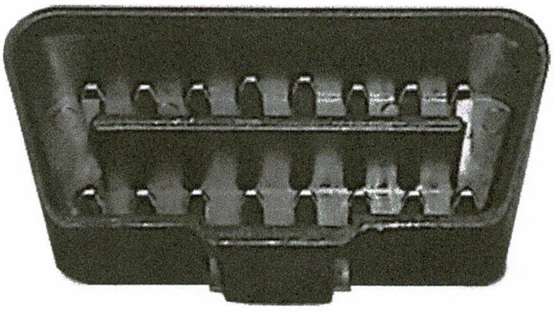


DIAGNOSTIC CONNECTOR

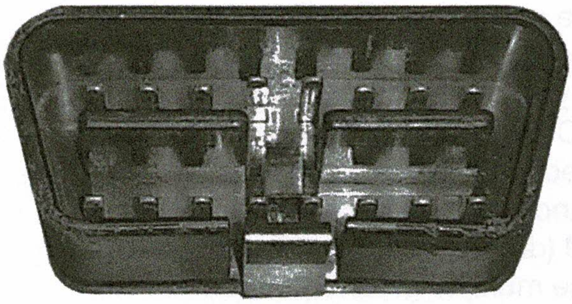
The Diagnostic Connector provides the link for a compatible Scan Tool to communicate with a vehicles control modules and is required to be within reach of the driver, generally below the steering column. Since the introduction of ADR79/01 this link is made using CAN Bus.


4. Chassis GND
3. *
2. J1850 BUS
1. *
Sensor GND .5
CAN High .6
K-Line .7
* .8
9. *
10. J1850 BUS
11. *
12. *
Battery + .16
L-Line .15
CAN Low .14
* .13

It should be noted that there are two types of the official SAE J1962 diagnostic connector:



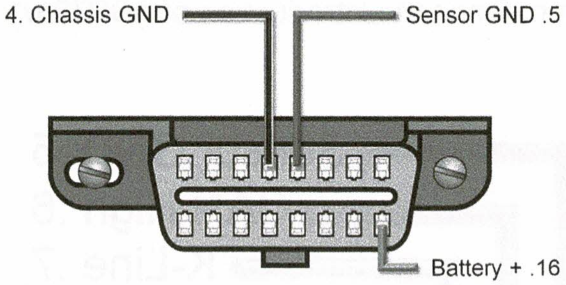
Type A - 12 Volts ONLY



Type B - 12 and 24 Volts compatible

DIAGNOSTIC CONNECTOR continued...

Ground and Power circuits



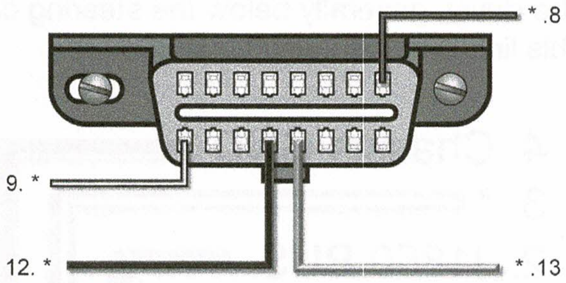
All vehicles fitted with a 16 pin OBD Connector should have the following:

Pin 4: Chassis Ground
This has been the configuration standard for this connector since its recommendation by the SAE in 1988.

Pin 5: Sensor Ground
(sometimes called Signal Ground)
The requirement for this circuit was added in 1996 in the US with the implementation of OBD-II and 2001 in Europe with the implementation of the EURO-III standard. Unlike the Chassis Ground which is usually grounded to the nearest ground point to the connector, the Sensor Ground is grounded to the same ground point as the ECM.
While a lot of documentation states that you can test the ECM Ground at the OBD Connector this is NOT entirely correct as it does not allow for loss of ground between the ground point and ECM (damaged wiring) and most ECM's utilise multiple ground points.

Pin 16: Unswitched Battery Volts

Discretionary circuits - Part I



Pins 8, 9, 12 and 13: Discretionary
These can be used by manufactures as they see fit. As these are discretionary there are no standard basic tests that can be applied.
Some example of manufacturers utilising these circuits are:

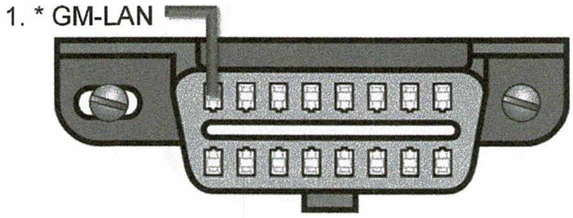
Pin 8: Nissan <2005
Manual diagnosis switch

Pin 8: Nissan >2005
Ignition Voltage

Pin 13: Toyota
Manual diagnosis switch

DIAGNOSTIC CONNECTOR continued...

Discretionary circuits - Part II

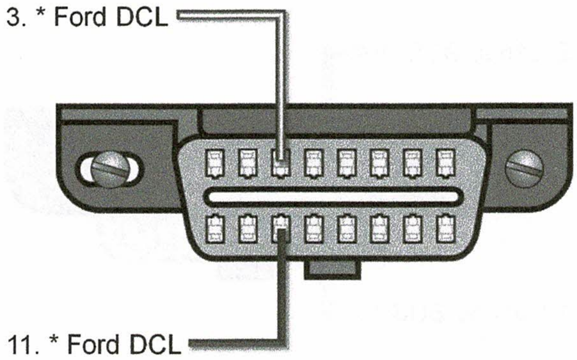


Pin 1: GM Low Speed LAN
Here is an example of a manufacturer using another discretionary circuit.

GM/Holden use Pin 1 for communication with their single wire the Low Speed Network.

As this is discretionary there are no standard basic tests that can be applied. However, the GM Low Speed LAN operates on a similar basis as the K-Line signal except it is reversed. It is a basic binary code, the idle voltage is 0 Volts with a signal voltage of Battery Volts.

Discretionary circuits - Part III



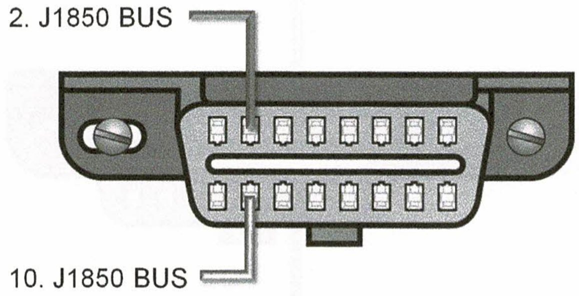
Pins 3 and 11: Ford DCL Network
Here is another example of a manufacturer using a discretionary circuit.

Ford use Pins 3 and 11 for communication with their two-wire Medium Speed Network.

As this is discretionary there are no standard basic tests that can be applied. However, the Ford DCL Network is similar to CAN BUS in its configuration. Therefore the Resistance Test for CAN Bus is also appropriate for Ford's DCL Network.

DIAGNOSTIC CONNECTOR continued...

J1850 BUS circuits



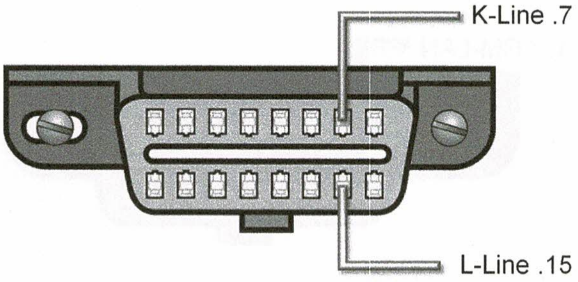
There are 2 types of J1850 Networks:

Pin 2: SAE-J1850 VPW
Used almost exclusively by GM in the US between 1996 & 2007 it is a single wire communication network (the only AU production vehicles to use this are the VY & VZ Gen. III V8's)

Pin 2 and 10: SAE-J1850 PWM
Used almost exclusively by Ford in the US between 1996 & 2007 it is a two wire communication network (the only AU production vehicles to use this are the AU series Falcon's)

The SAE-J1850 PWM was pretty much a precursor for CAN Bus. It has many of the same capabilities, however J1850 was only recognised by SAE in the US so when OBDII was updated in 2008 the ISO CAN Bus protocol was adopted because of its international compliance.

ISO9141 and KWP2000



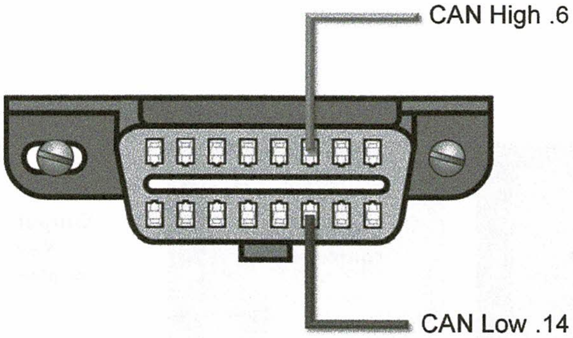
The ISO9141-2 & ISO14230-4 (KWP2000) protocols are most commonly known as the K-Line & L-Line. These are International Standard (ISO) protocols and were used for most pre-CAN Bus vehicles in Europe and Asia, as well as by the Chrysler group in the US. Therefore these are the most common pre-CAN Bus protocols in AU.

Pin 15: L-Line
In very early ISO9141-2 protocols Scan Tools used the L-Line to send a request to the ECM to create a Link with the Scan Tool. Then all of the communication was done via the K-Line.

Pin 7: K-Line
All other pre-CAN Bus ISO protocols do not require the L-Line and all communication is done on the K-Line (this is by far the most common pre-CAN Bus ISO configuration). The K-Line signal is a basic binary code, the idle voltage is Battery Volts (Binary 1) with a signal voltage of 0 Volts (Binary 0). The K-Line will not usually command a signal unless it is triggered to do so by a Scan Tool. The K-Line is of such basic design that is not able to communicate with multiple Nodes (Control Modules) simultaneously, it must connect with each node individually.

DIAGNOSTIC CONNECTOR continued...

CAN Bus circuit



Pins 6 and 14: CAN Bus

The CAN Bus (Controller Area Network Bus) was developed by Bosch to fulfil its intra-vehicle communication needs. Although Bosch started on CAN Bus in 1983 and completed V1.0 in 1986 it wasn't until 2001 that it started to gain popularity.

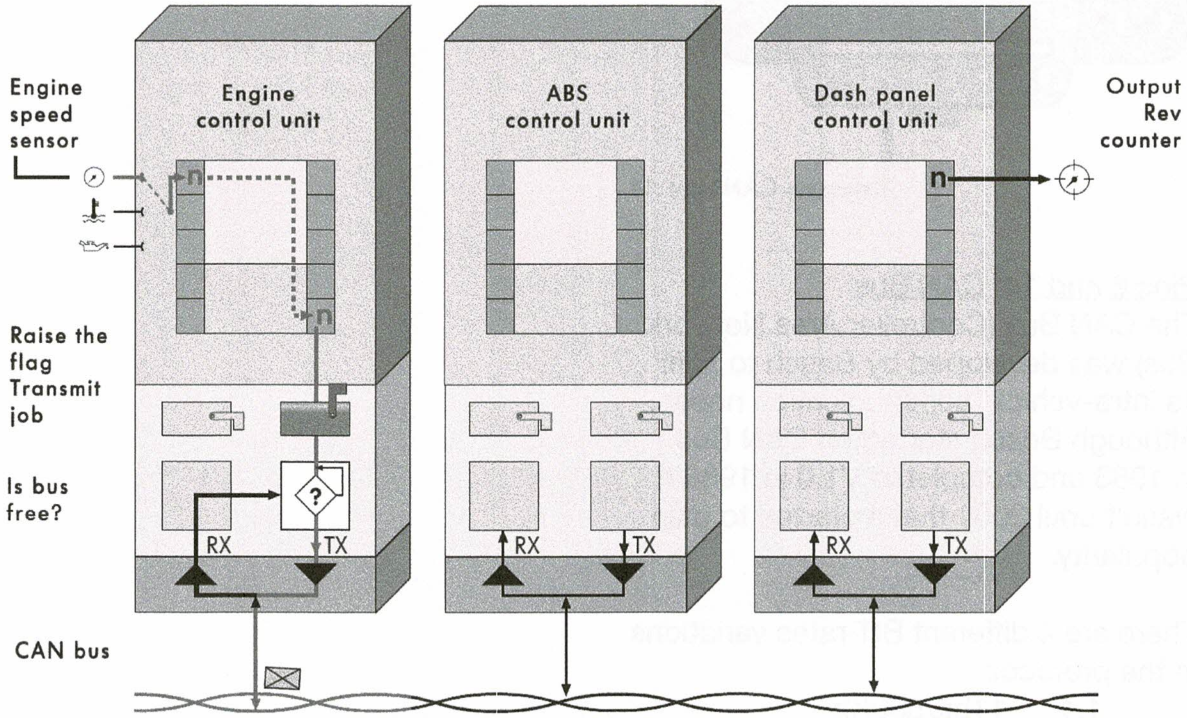
There are 4 different BIT-rates variations in the protocol:

1.1	11bit/500Kb
1.2	29bit/500Kb
1.3	11bit/250Kb
1.4	29bit/250Kb

THE MESSAGE

The process of sending and receiving CAN messages is best described using the following diagrams:

Sending

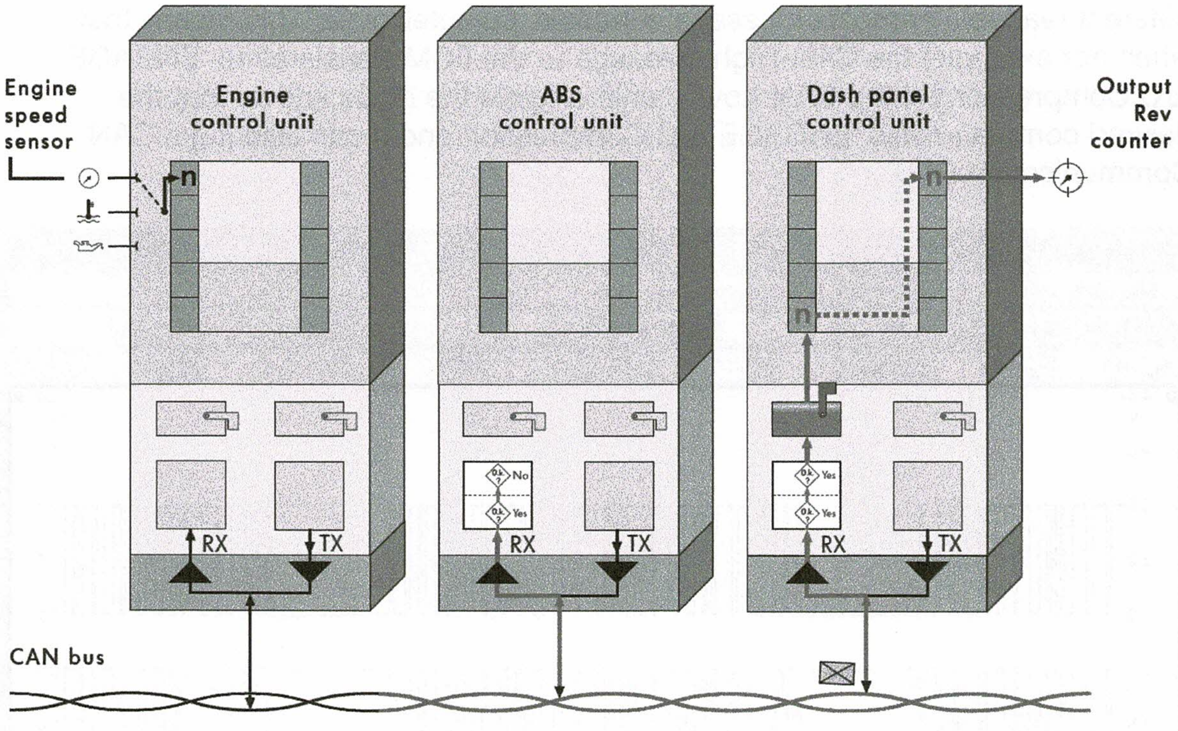

Engine speed sensor
Engine control unit
ABS control unit
Dash panel control unit
Output Rev counter
n
n
n
Raise the flag Transmit job
Is bus free?
?
RX
TX
RX
TX
RX
TX
CAN bus

Start of a transmit process

1. Engine speed (n) is received as an input at the ECU
2. The voltage waveform is processed by the ECU
3. The ECU outputs the value 'n' in the form of a digital message
4. The CAN Controller adds details such as origin, priority and checksum
5. The message is placed in the outgoing mailbox
6. The CAN Controller waits for a free space on the CAN Bus
7. Once a space is found the Transceiver sends the message.

THE MESSAGE continued...

Receiving

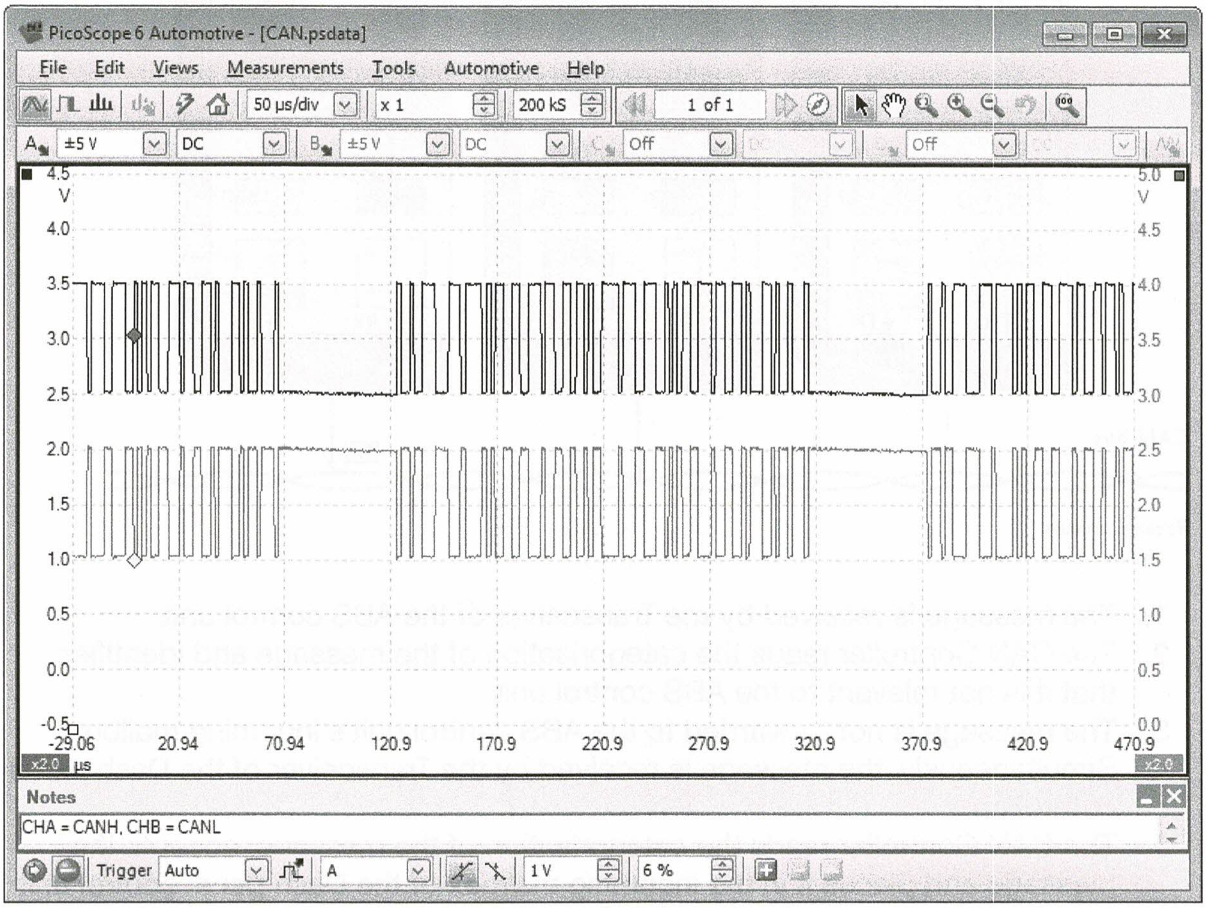

Engine speed sensor
Engine control unit
ABS control unit
Dash panel control unit
Output Rev counter
n
n
n
No
Yes
Yes
Yes
RX
TX
RX
TX
RX
TX
CAN bus

Receive process

1. The message is received by the Transceiver of the ABS control unit
2. The CAN Controller reads the categorisation of the message and identifies that it is not relevant to the ABS control unit
3. The message is not forwarded to the ABS control unit's incoming mailbox
4. Simultaneously, the message is received by the Transceiver of the Dash panel control unit
5. The CAN Controller reads the categorisation of the message, accepts the message and places it in the incoming mailbox of the Dash panel control unit
6. The Dash panel control unit processes the data and outputs a voltage waveform that controls the Tachometer (Rev counter).

THE MESSAGE continued...

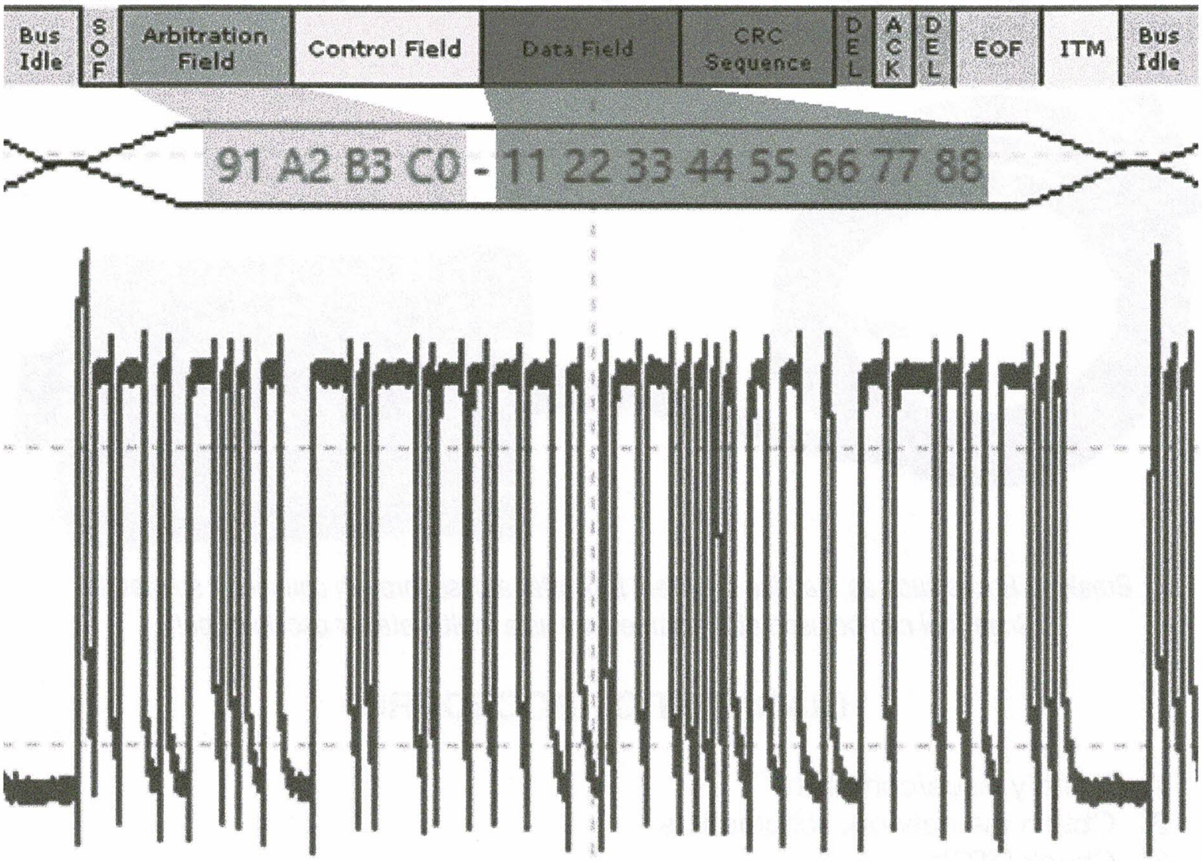
The CAN BUS protocol uses 2 signals that are a perfect mirror image of each other. In automotive vehicles, messages are sent simultaneously down two communication lines (CAN-High & CAN-Low). This allows Nodes to identify corrupted messages on the network and act upon them. When a corruption to a CAN message occurs it does not convert the complex message into a different readable complex message, it makes it unintelligible. This means that when (for example) the CAN-High message to the ECM translates to 'ENGAGE A/C Compressor yet the CAN-Low is unintelligible the Node knows that the desired command was 'ENGAGE A/C Compressor' and it can also log a CAN Communication DTC.


PicoScope 6 Automotive - [CAN.psdata]
File Edit Views Measurements Tools Automotive Help
50 µs/div
x 1
200 kS
1 of 1
A ±5 V DC
B ±5 V DC
Off
Off
4.5 V
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
5.0 V
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-29.06
20.94
70.94
120.9
170.9
220.9
270.9
320.9
370.9
420.9
470.9
µs
x2.0
Notes
Trigger Auto
A
1 V
6 %

CHA = CANH, CHB = CANL

THE MESSAGE continued...

The following image provides a graphical representation of how the CAN Controller decodes a CAN signal into a serial data message:


Bus Idle
SOF
Arbitration Field
Control Field
Data Field
CRC Sequence
DEL
ACK
DEL
EOF
ITM
Bus Idle
91 A2 B3 C0 - 11 22 33 44 55 66 77 88

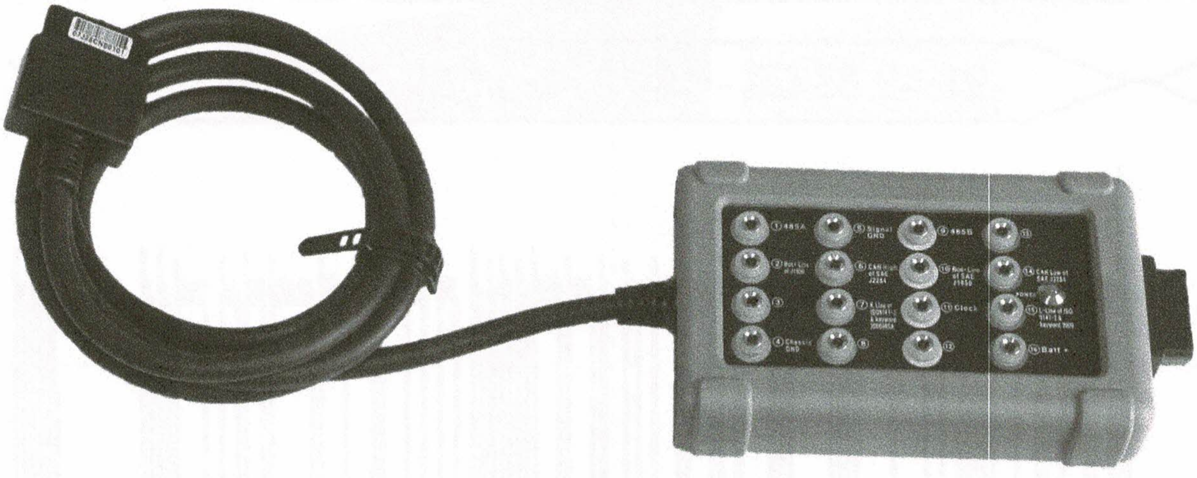
Decoding software such as that provided with the Pico Automotive Scope focuses on two fields:

- Arbitration Field - This is the identifier which also includes the priority
- Data Field - the data field is the only field that has a variable length and can contain up to 64 bits, this field is includes the main message

The CAN serial data message and decoding is significantly more complex than the basic example provided above, this will be explored further in future clinics.

ACCESSING THE DATA

While the Diagnostic Link Connector (DLC) is the obvious connection point, it should only be used with an official SAE J1962 male connector to avoid spreading of the terminals. If carrying out diagnostics on the DLC it is recommended that a Breakout Box is utilised.



Breakout Boxes such as the Pico CAN Test Box offer a pass through connector so that the Scan Tool can be used at the same time as a multimeter or oscilloscope!

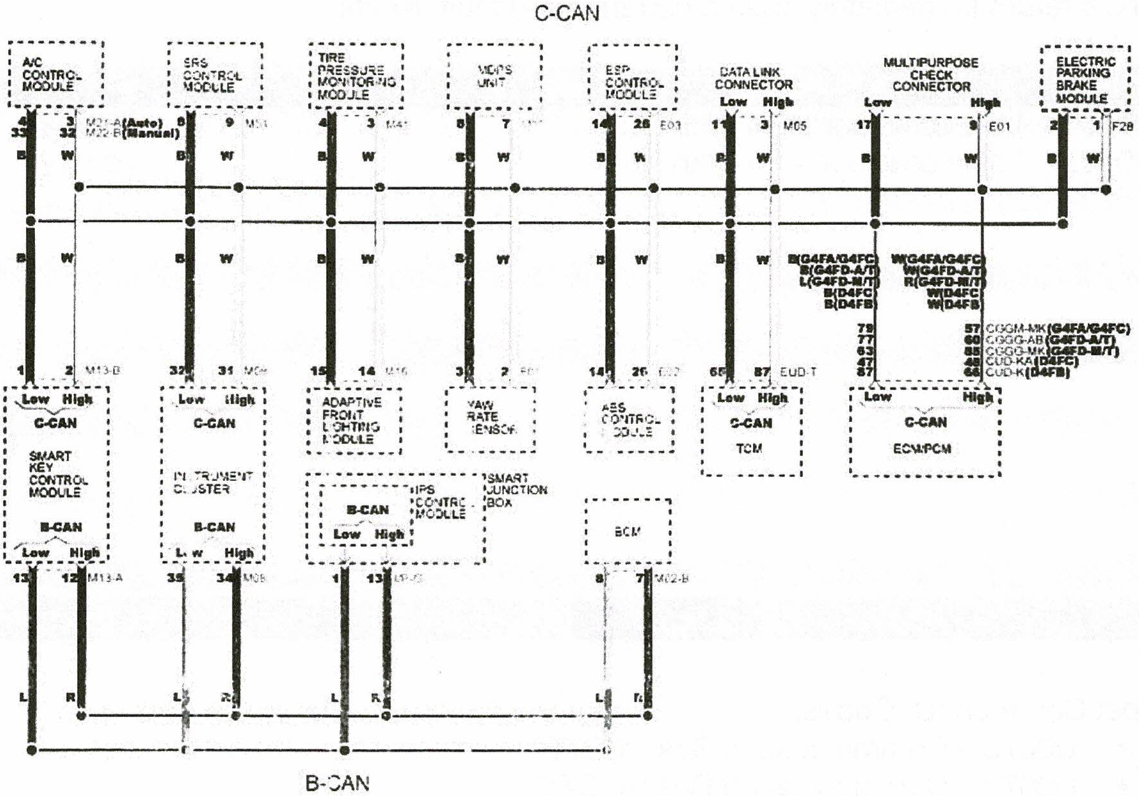
DIAGNOSTIC PROCEDURE

1. Identify issue/complaint
2. Obtain the network schematic/s
3. Check DTC's
4. Check data transfer with Breakout Box or Scan Tool
5. Check resistance between terminals 6 & 14
6. Check voltage between terminals 6 & 14
7. Check for short to ground at terminals 6 & 14
8. Function Test - Check message sent in Scan Tool Data
9. Function Test - Check carry out command with Scan Tool Actuation
10. Check waveforms with an Oscilloscope

Identify issue/complaint
The first step in any diagnosis is witnessing the fault.
You'll need to know when the fault occurs and if possible how to make it fault.
Better still, have the driver of the vehicle show you the fault!

DIAGNOSTIC PROCEDURE continued...

Obtain the network schematic/s
The best way of obtaining an understanding of the CAN Bus is to review the schematic diagram. In the following example for an Hyundai i30 there are a number of factors evident that will assist in the diagnostic process:


C-CAN
A/C CONTROL MODULE
SRS CONTROL MODULE
TIRE PRESSURE MONITORING MODULE
MDPS UNIT
ESP CONTROL MODULE
DATA LINK CONNECTOR
Low High
MULTIPURPOSE CHECK CONNECTOR
Low High
ELECTRIC PARKING BRAKE MODULE
M21-A(Auto)
M22-B(Manual)
M05
E01
E03
F28
B(G4FA/G4FC)
B(G4FD-A/T)
L(G4FD-M/T)
B(D4FC)
B(D4FB)
W(G4FA/G4FC)
W(G4FD-A/T)
R(G4FD-M/T)
W(D4FC)
W(D4FB)
CGGM-MK(G4FA/G4FC)
CGGG-AB(G4FD-A/T)
CGGG-MK(G4FD-M/T)
CUD-KA(D4FC)
CUD-K(D4FB)
M13-B
EUD-T
Low High
C-CAN
SMART KEY CONTROL MODULE
B-CAN
Low High
M13-A
Low High
C-CAN
INSTRUMENT CLUSTER
B-CAN
Low High
M05
ADAPTIVE FRONT LIGHTING MODULE
YAW RATE SENSOR
ABS CONTROL MODULE
C-CAN
TCM
C-CAN
ECM/PCM
IPS CONTROL MODULE
B-CAN
Low High
SMART JUNCTION BOX
BCM
M02-B
B-CAN

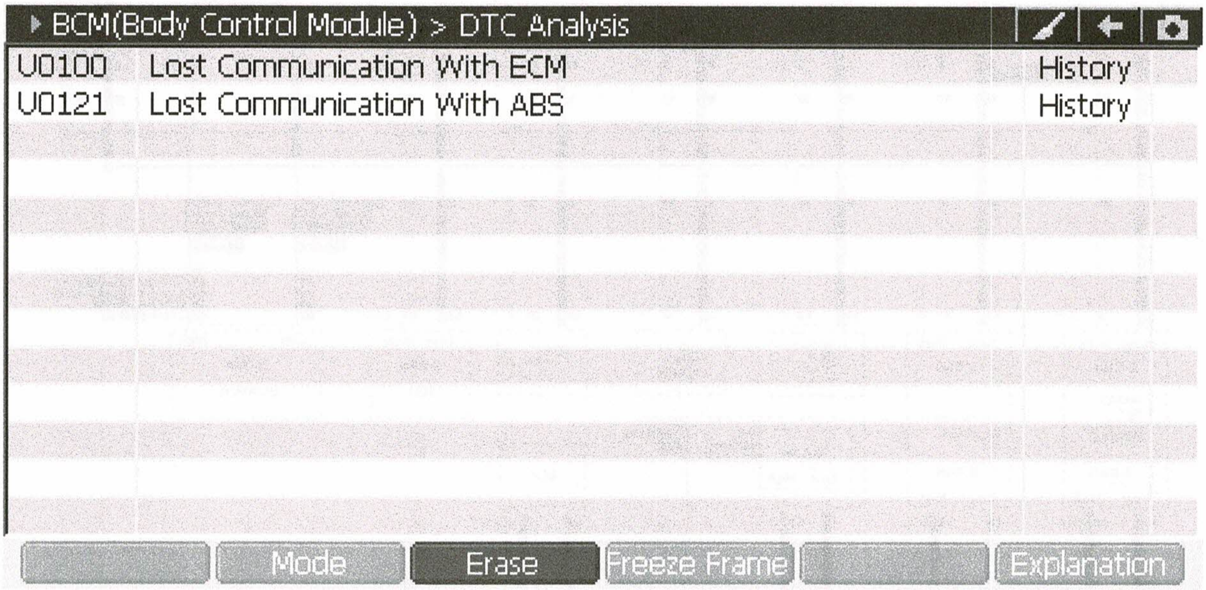
- There are two CAN's
  C-CAN is the primary network (identified by the location of the DLC)
  B-CAN is the secondary network
- The DLC states that CAN Low is at Pin 11 and CAN High is at Pin 3
  A check of the DLC diagram shows that Hyundai reverse the numbering sequence and the typical pins are used
- The configuration of the networks is of a parallel format
- Both the Instrument Cluster and the Smart Key Control Module communicate on both networks, the written description of the CAN confirmed that the Instrument Cluster is the Gateway Module.

Another example is provided back on page 4, the example from a VF Commodore shows a Series configuration and the resisters that create the Terminating Nodes.

DIAGNOSTIC PROCEDURE continued...

Check DTC's

The checking of DTC's is always a logical starting point to start your on-vehicle diagnostics. When it comes to CAN systems it is not uncommon for 'U' codes to be found. These are often explained by power interruptions and should be noted (either by screen capture or by noting them on the repair order) and cleared. If the DTC's return immediately, then a current 'hard fault' exists.



▸ BCM(Body Control Module) > DTC Analysis

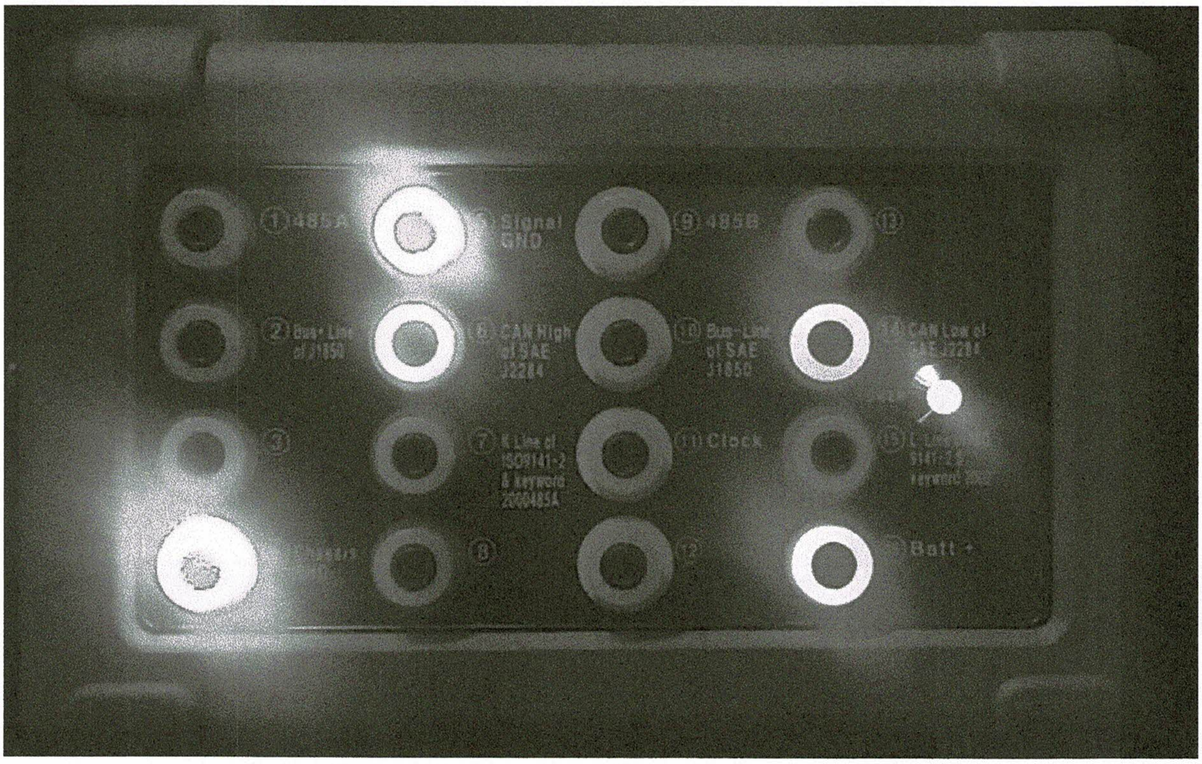
U0100	Lost Communication With ECM	History
U0121	Lost Communication With ABS	History

Most Common 'U' Codes:

- U0073 – Communication Bus 'A' OFF
- U0074 – Communication Bus 'B' OFF
- U0100 – Lost Communication with ECM/PCM
- U0101 – Lost Communication with TCM
- U0102 to U0299 – Lost Communication with *** Module
- U0300 to U0399 – Software Incompatibility with *** Module, these usually occur when modules are replaced and/or incorrectly paired
- U0400 to U0499 – Invalid Data from *** Module

DIAGNOSTIC PROCEDURE continued...

Check data transfer with Breakout Box or Scan Tool
If you are using a Breakout Box on the DLC these will usually include LED confirmation lights. If equipped these will provide an immediate confirmation of the networks that are communicating with the DLC.

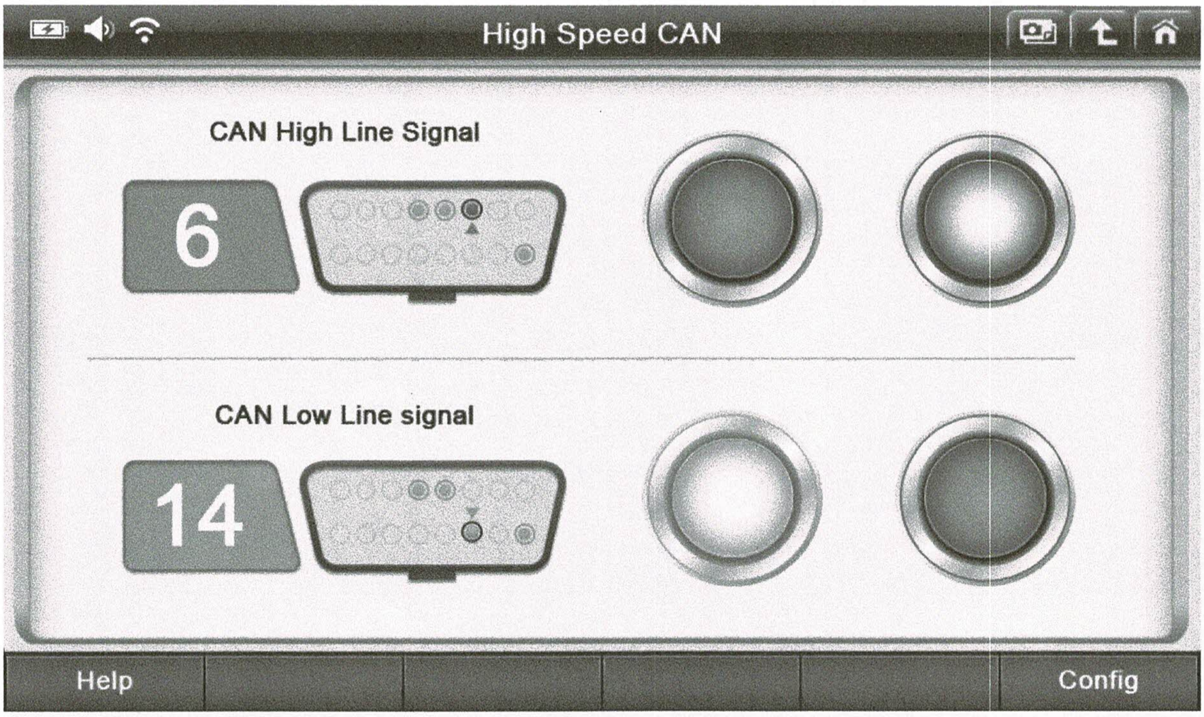

① 485A
⑤ Signal GND
⑨ 485B
⑬
② Bus+ Line of J1850
⑥ CAN High of SAE J2284
⑩ Bus- Line of SAE J1850
⑭ CAN Low of SAE J2284
③
⑦ K Line of ISO9141-2 & keyword 2000485A
⑪ Clock
⑧
⑫
Batt +

In the image above the confirmation LED's are visible for:

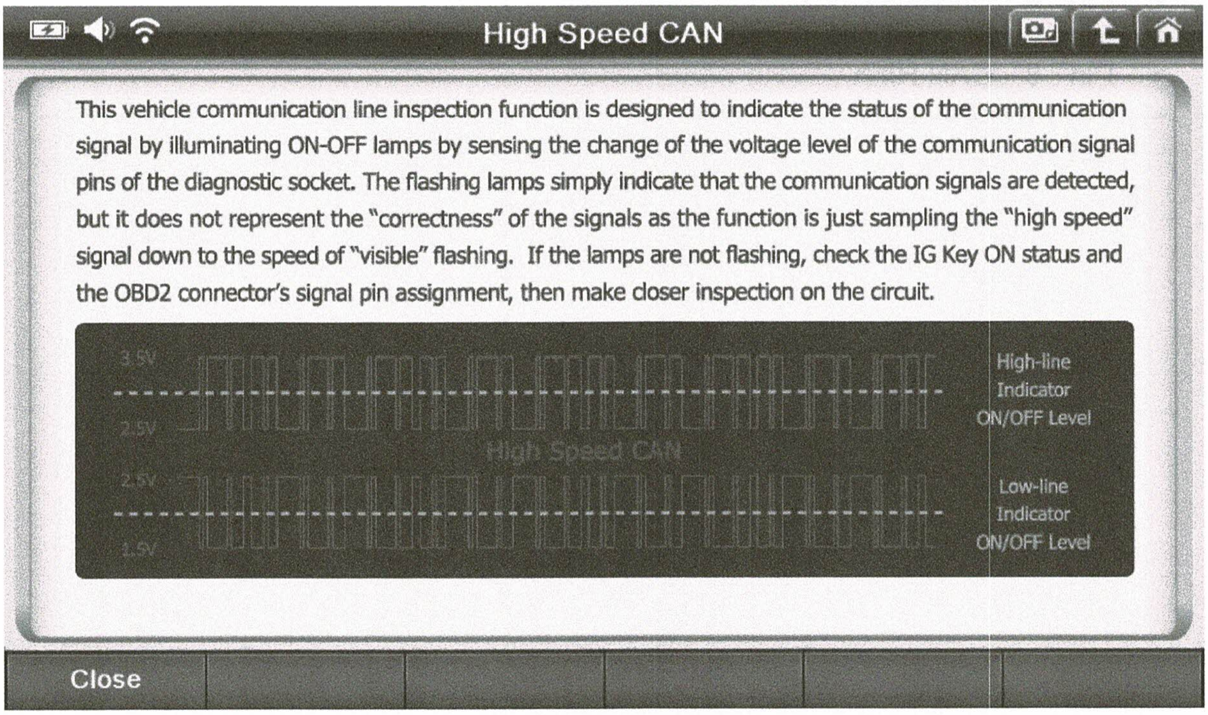
- Pin 4 - Chassis GND
- Pin 5 - Signal GND
- Pin 6 - CAN High
- Pin 14 - CAN Low
- Pin 16 - Batt+

DIAGNOSTIC PROCEDURE continued...

If you do not have a Breakout Box with confirmation lights it is possible to do a network check with some Scan Tools. The following image is from the G-Scan2:


High Speed CAN
CAN High Line Signal
6
CAN Low Line signal
14
Help
Config

Tools such as the G-Scan2 only display the status of the CAN Voltages measured at the DLC. This means that if the CAN Bus is intact between the two Terminating Resisters and the DLC then any faults will not be identified. The following image describes the function of the CAN Signal Indicator.


High Speed CAN

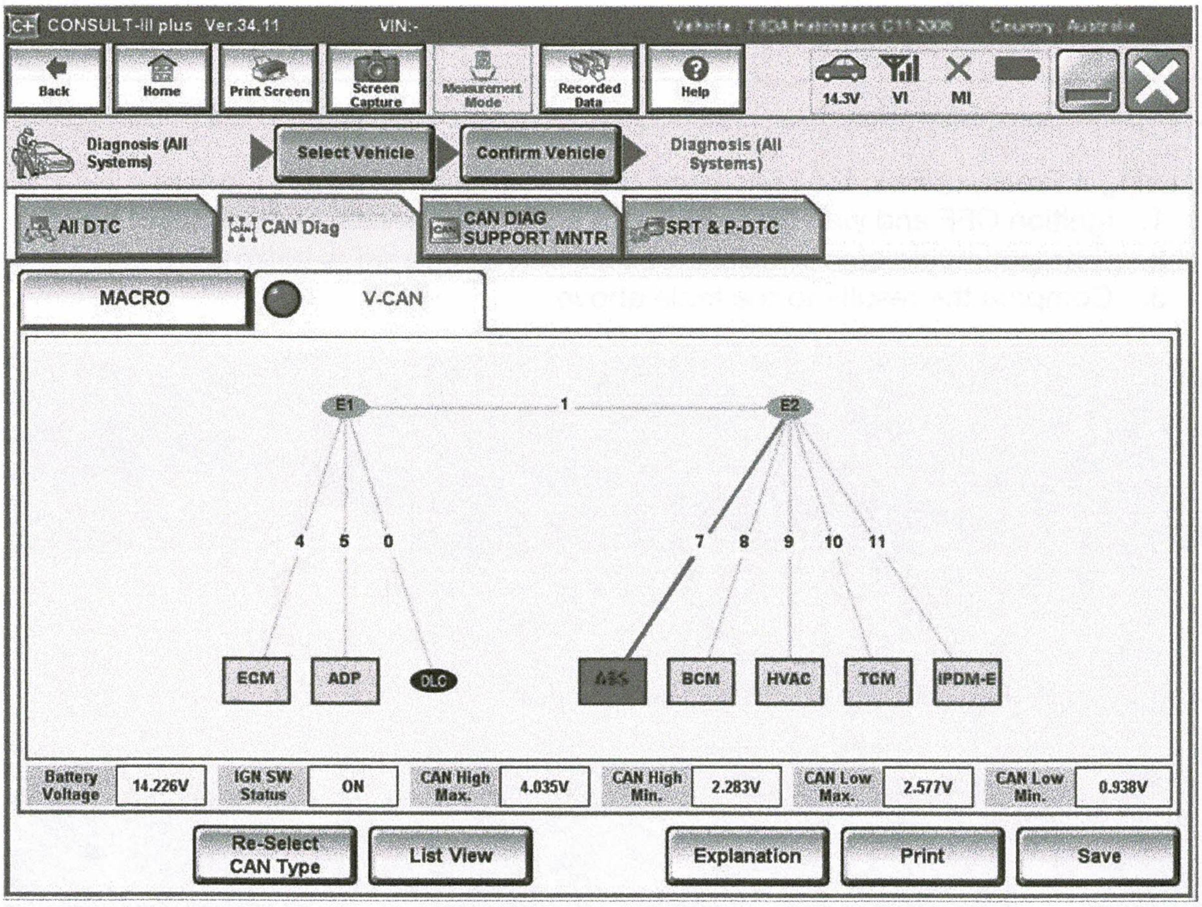
This vehicle communication line inspection function is designed to indicate the status of the communication signal by illuminating ON-OFF lamps by sensing the change of the voltage level of the communication signal pins of the diagnostic socket. The flashing lamps simply indicate that the communication signals are detected, but it does not represent the "correctness" of the signals as the function is just sampling the "high speed" signal down to the speed of "visible" flashing. If the lamps are not flashing, check the IG Key ON status and the OBD2 connector's signal pin assignment, then make closer inspection on the circuit.

3.5V
2.5V
High Speed CAN
2.5V
1.5V
High-line Indicator ON/OFF Level
Low-line Indicator ON/OFF Level
Close

DIAGNOSTIC PROCEDURE continued...

Some original equipment (OE) dealer tools have a much greater level of functionally, such as the Nissan Consult-III Plus which includes a CAN Diagnosis function.

The Scan Tool sends a message to each Node and waits for a response. Using a combination of vehicle specifications that are loaded into the tool and a the responses received off of the CAN the Scan Tool builds a graphical representation of the vehicle network, highlighting functioning sections in green and nonresponsive Nodes in red.


CONSULT-III plus Ver.34.11
VIN:-
Back
Home
Print Screen
Screen Capture
Measurement Mode
Recorded Data
Help
14.3V
VI
MI
Diagnosis (All Systems)
Select Vehicle
Confirm Vehicle
Diagnosis (All Systems)
All DTC
CAN Diag
CAN DIAG SUPPORT MNTR
SRT & P-DTC
MACRO
V-CAN
E1
1
E2
4
5
0
7
8
9
10
11
ECM
ADP
DLC
ABS
BCM
HVAC
TCM
IPDM-E
Re-Select CAN Type
List View
Explanation
Print
Save

Battery Voltage 14.226V
IGN SW Status ON
CAN High Max. 4.035V
CAN High Min. 2.283V
CAN Low Max. 2.577V
CAN Low Min. 0.938V

In this example the Nissan Consult-III Plus Scan Tool has identified an issue with the network connection to the ABS Module.

Unfortunately this level of functionality is reserved for OE Scan Tools.

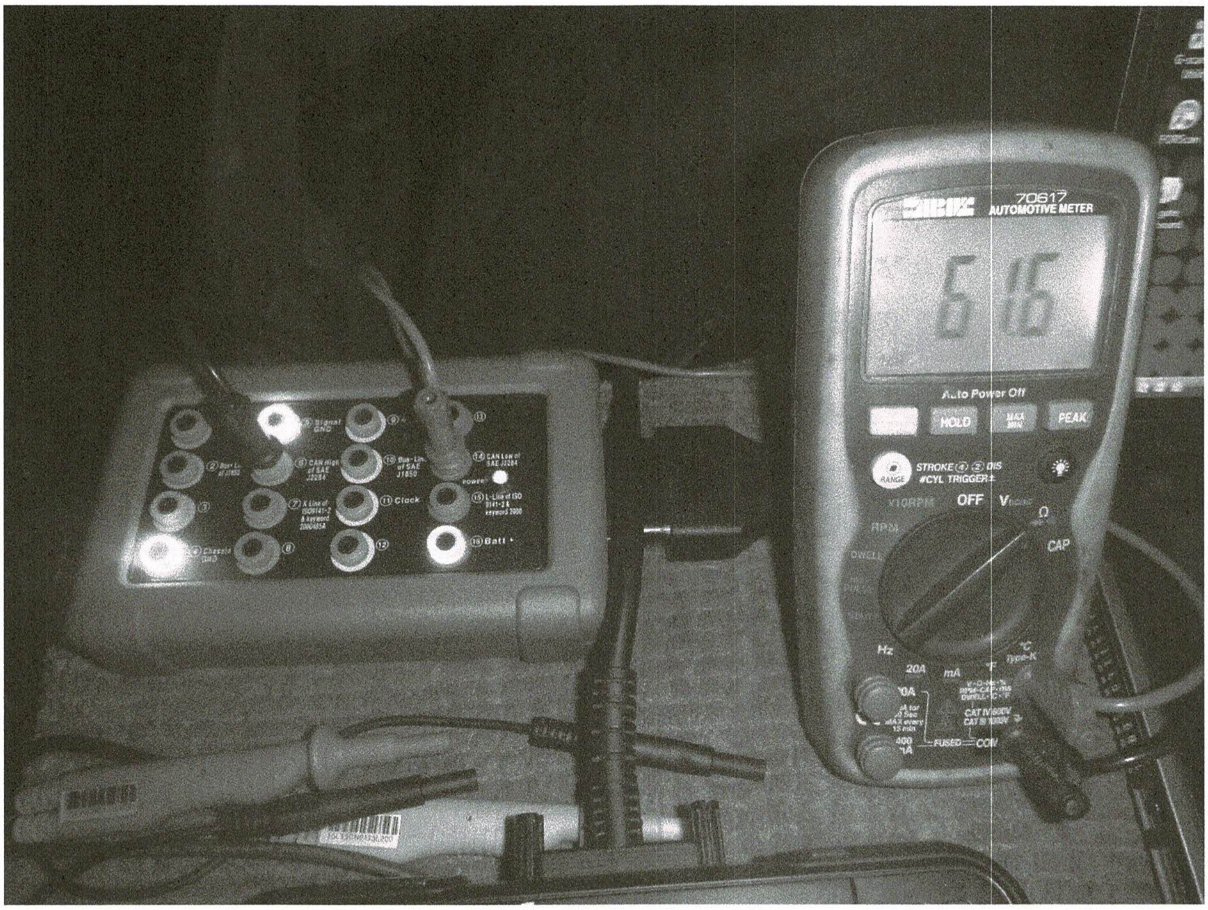
DIAGNOSTIC PROCEDURE continued...

Check resistance between terminals 6 & 14
Checking the resistance across the CAN-High (Pin 6) and CAN-Low (Pin 14) circuit at the DLC provides a quick check of the CAN Bus integrity. The result should be within 15% of 60Ω. The following table provides outcomes and possible causes:

Result	Condition
51 to 69Ω	Normal
<51Ω	Short Circuit
70 to 102Ω	High Resistance
102 to 138Ω	Open Circuit
∞ (Infinite Ohms)	Multiple Open Circuits

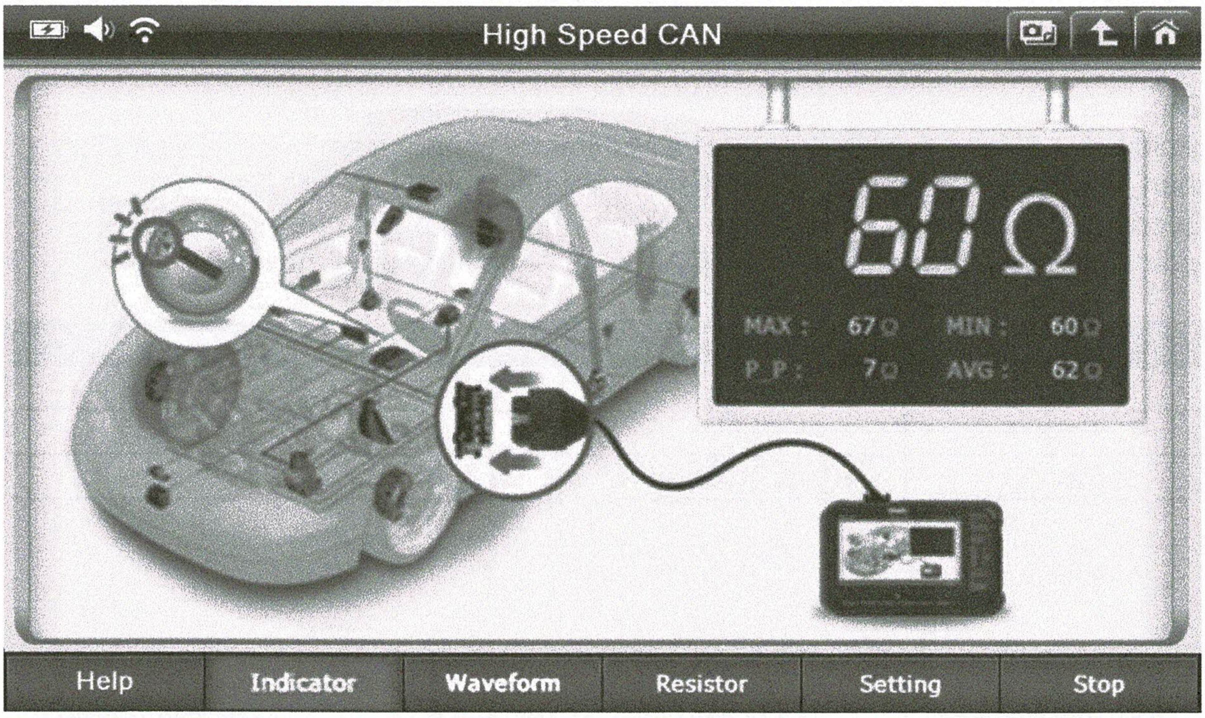
If using a Breakout Box, the resistance check is a quick and easy process:

1. Ignition OFF and wait for modules to enter sleep mode or disconnect battery
2. Connect multimeter in resistance test with leads across terminals 6 and 14
3. Compare the results to the table above


70617
AUTOMOTIVE METER
61.6
Auto Power Off
HOLD
MAX MIN
PEAK
RANGE
STROKE 4 2 DIS
#CYL TRIGGER±
OFF
CAP
COM
Signal GND
Chassis GND
CAN High of SAE J2284
CAN Low of SAE J2284
Clock
Batt +

DIAGNOSTIC PROCEDURE continued...

Some Scan Tools may also include this function. The following example is from the G-Scan2 with the optional VMI kit:



High Speed CAN

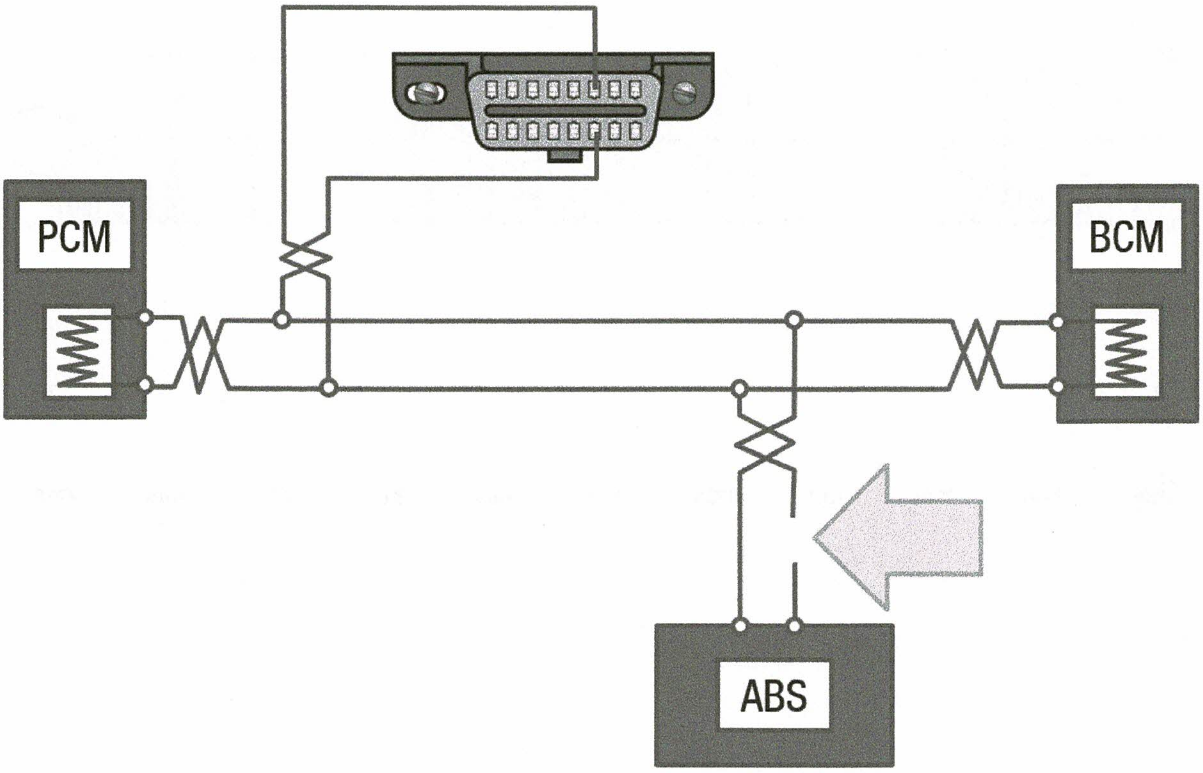
60 Ω

MAX : 67Ω MIN : 60Ω

P_P : 7Ω AVG : 62Ω

Help
Indicator
Waveform
Resistor
Setting
Stop

It should be noted that a resistance test cannot identify all CAN Bus infrastructure failures. The following example shows how an open circuit on a sub-branch of the network will not affect the resistance:

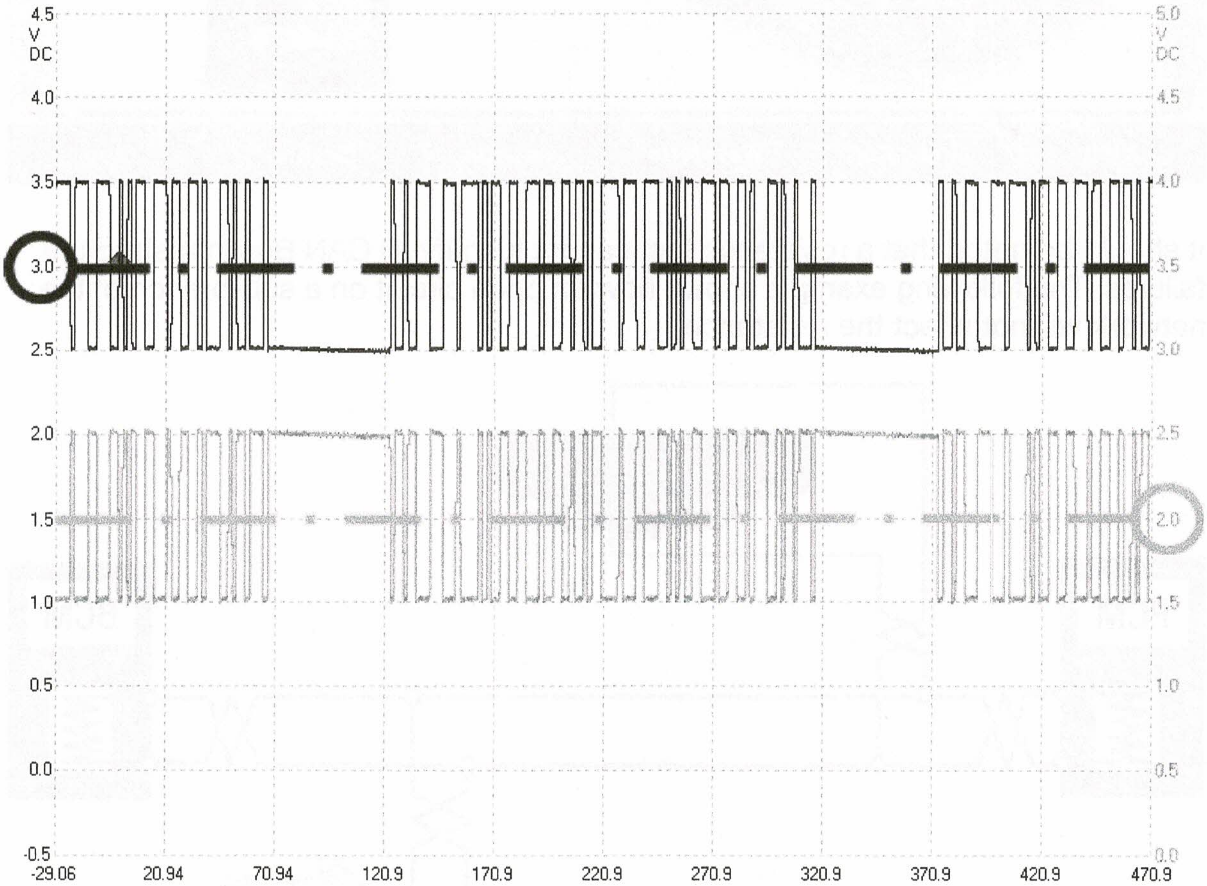


DIAGNOSTIC PROCEDURE continued...

Check voltage between terminals 6 & 14
Checking the CAN Bus voltage at the DLC checks how the Nodes (Control Modules) are using the network (as opposed to the resistance test that checked the integrity of the network).

Because of the speed of the Bus signals they are immeasurable with an Automotive Multimeter. Even a quality Automotive Multimeter cannot measure signals faster than 1mS (0.001 Seconds). CAN Bus operates as quickly as 1µS (0.000001 Seconds). This is why the Multimeter display shows the average voltage as indicated by the centre-line on the CAN BUS Scope patterns, see below:

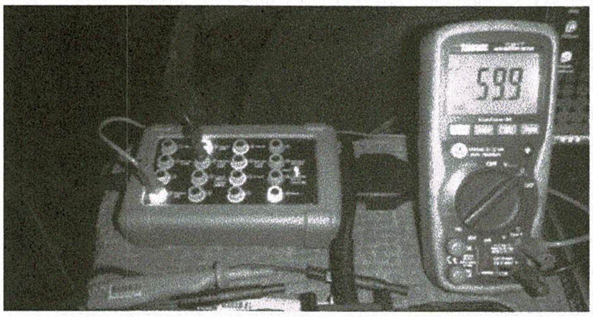
DLC Pins	Test	Result	Condition
4 and 6	Voltage	≈3.0V	Normal
4 and 14		≈2.0V	Normal
6 and 14	Differential Voltage	≈1.0V	Normal



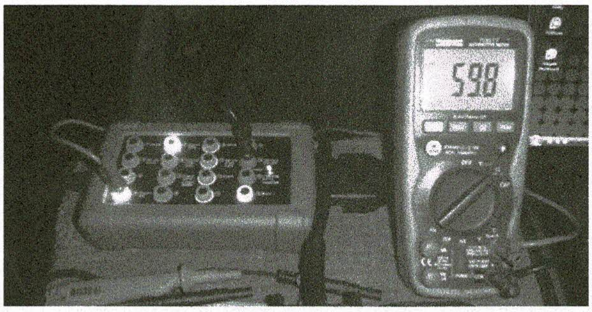
DIAGNOSTIC PROCEDURE continued...

Check for short to ground at terminals 6 & 14
Because CAN Bus uses a floating ground (not grounded to the chassis of the vehicle), a short to ground will not alter the CAN resistance. A very easy check is to measure the resistance between the pins 6 and 14 to the ground pin/s of the DLC. The example below shows the testing of all 4 combinations (all values in kΩ):

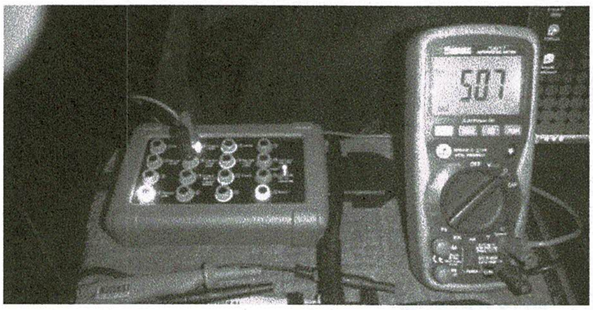
Terminals 4 & 6



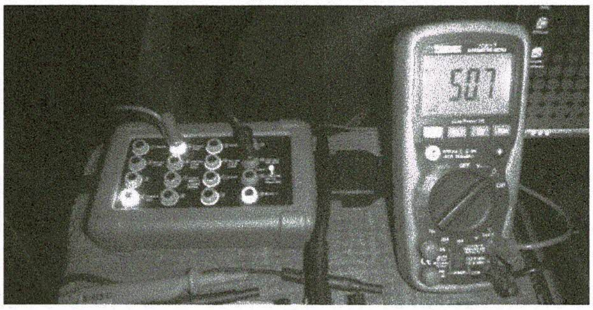
Terminals 4 & 14



Terminals 5 & 6



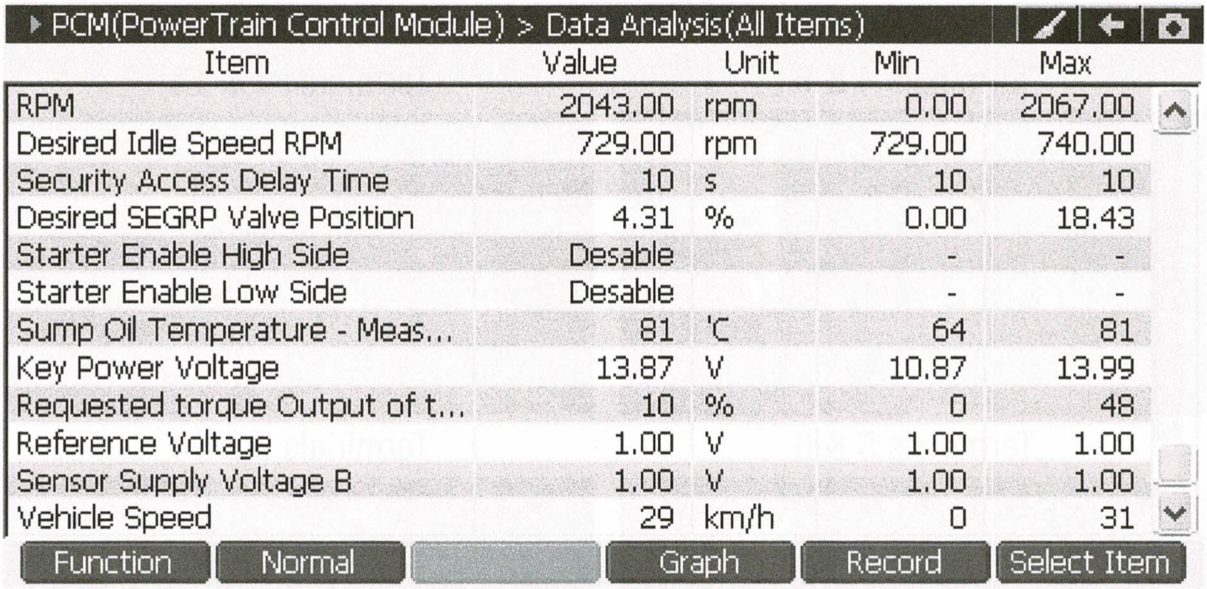
Terminals 5 & 14



Note: *Early CAN vehicles (1988 to 2005) quite often used shielded twisted pair wiring, as the shield was grounded it made these vehicles more susceptible to short to ground failures if the harness suffered an impact!*

DIAGNOSTIC PROCEDURE continued...

Function Test - Check message sent in Scan Tool Data
Monitor the data tables for values that are known to originate from another Control Module on the CAN Bus. An easy example that is relevant to most vehicles is the Vehicle Speed value that originates at the ABS Control Module:

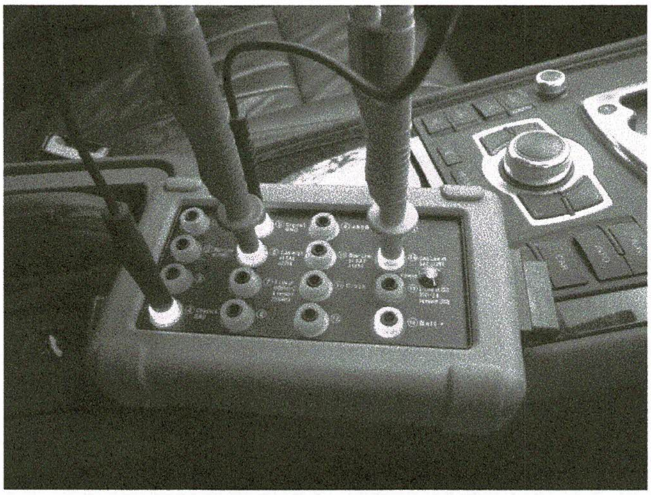

PCM(PowerTrain Control Module) > Data Analysis(All Items)

Item	Value	Unit	Min	Max
RPM	2043.00	rpm	0.00	2067.00
Desired Idle Speed RPM	729.00	rpm	729.00	740.00
Security Access Delay Time	10	s	10	10
Desired SEGRP Valve Position	4.31	%	0.00	18.43
Starter Enable High Side	Desable		-	-
Starter Enable Low Side	Desable		-	-
Sump Oil Temperature - Meas...	81	'C	64	81
Key Power Voltage	13.87	V	10.87	13.99
Requested torque Output of t...	10	%	0	48
Reference Voltage	1.00	V	1.00	1.00
Sensor Supply Voltage B	1.00	V	1.00	1.00
Vehicle Speed	29	km/h	0	31

Function Test - Check carry out command with Scan Tool Actuation
Actuation tests also prove CAN function. If for example a suspected fault exists with the CAN connection to the BCM, try using the Scan Tool to trigger the door lock actuators. If they cycle CAN is presently functioning.

DIAGNOSTIC PROCEDURE continued...

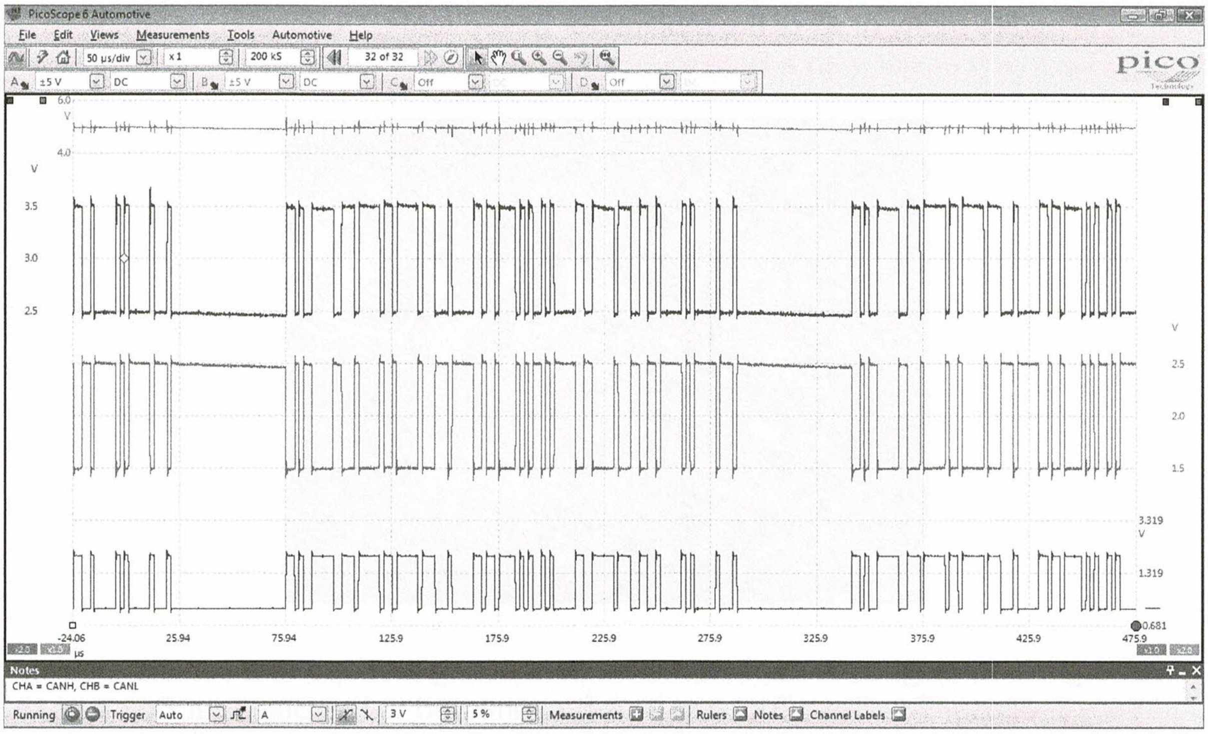
Check waveforms with an Oscilloscope
Oscilloscopes provide the ability to delve much deeper into CAN Bus diagnosis as well as expedite many or all of the multimeter based tests. Connecting a scope to the DLC is much easier with a Breakout Box:



A well organised diagnostic cabinet makes connecting a scope to a vehicle a quick and easy process. The Scan Tool can be left connected to the Breakout Box and all of the diagnostic leads and probes are within arms reach:

WAVEFORM EXAMPLES

Normal CAN signal with Math Channels


PicoScope 6 Automotive
File Edit Views Measurements Tools Automotive Help
50 µs/div
x1
200 kS
32 of 32
pico
A ±5 V DC
B ±5 V DC
C Off
D Off
6.0
V
4.0
3.5
3.0
2.5
2.0
1.5
3.319
V
1.319
0.681
-24.06
25.94
75.94
125.9
175.9
225.9
275.9
325.9
375.9
425.9
475.9
µs
Notes
Running
Trigger Auto
A
3 V
5 %
Measurements
Rulers
Notes
Channel Labels

CHA = CANH, CHB = CANL

Math Channel A + B is the upper waveform on the adjacent left side scale
CAN High is the upper centre waveform on the adjacent left side scale
CAN Low is the lower centre waveform on the adjacent right side scale
Math Channel A - B is the lower waveform on the adjacent right side scale

Math channels are a calculated scope pattern based on an equation, for this example there are 2 basic equations:

A + B (the top waveform)

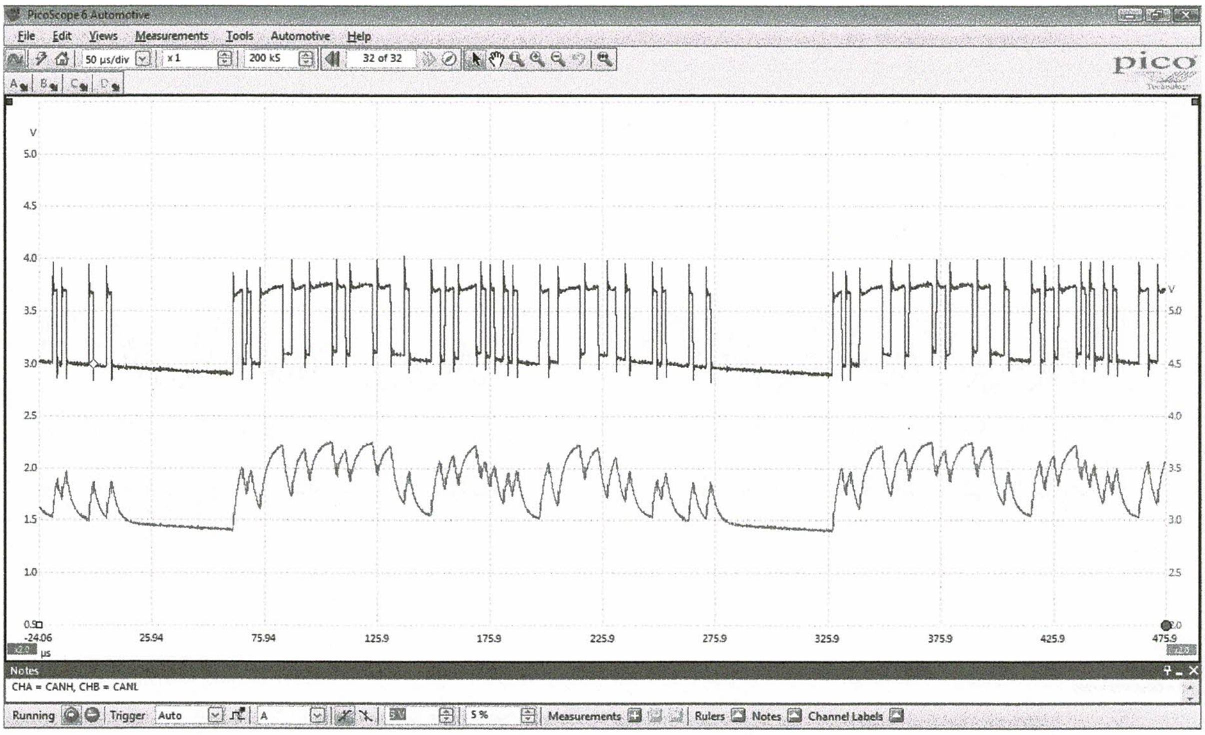
- The average of A + B should always be 5 Volts
- This feature provides an easy way to identify errors in the message, if the waveform deviates from 5 Volts an error has occurred

A – B (the bottom waveform)

- The average of A - B should always be a 0 to 2 Volts waveform
- This feature can be helpful in cleaning up static from the waveform

WAVEFORM EXAMPLES continued...

CAN Low OPEN Circuit


PicoScope 6 Automotive
File
Edit
Views
Measurements
Tools
Automotive
Help
50 µs/div
x1
200 kS
32 of 32
pico
A
B
C
D
V
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.50
-24.06
25.94
75.94
125.9
175.9
225.9
275.9
325.9
375.9
425.9
475.9
µs
Notes
Running
Trigger
Auto
A
5 %
Measurements
Rulers
Notes
Channel Labels

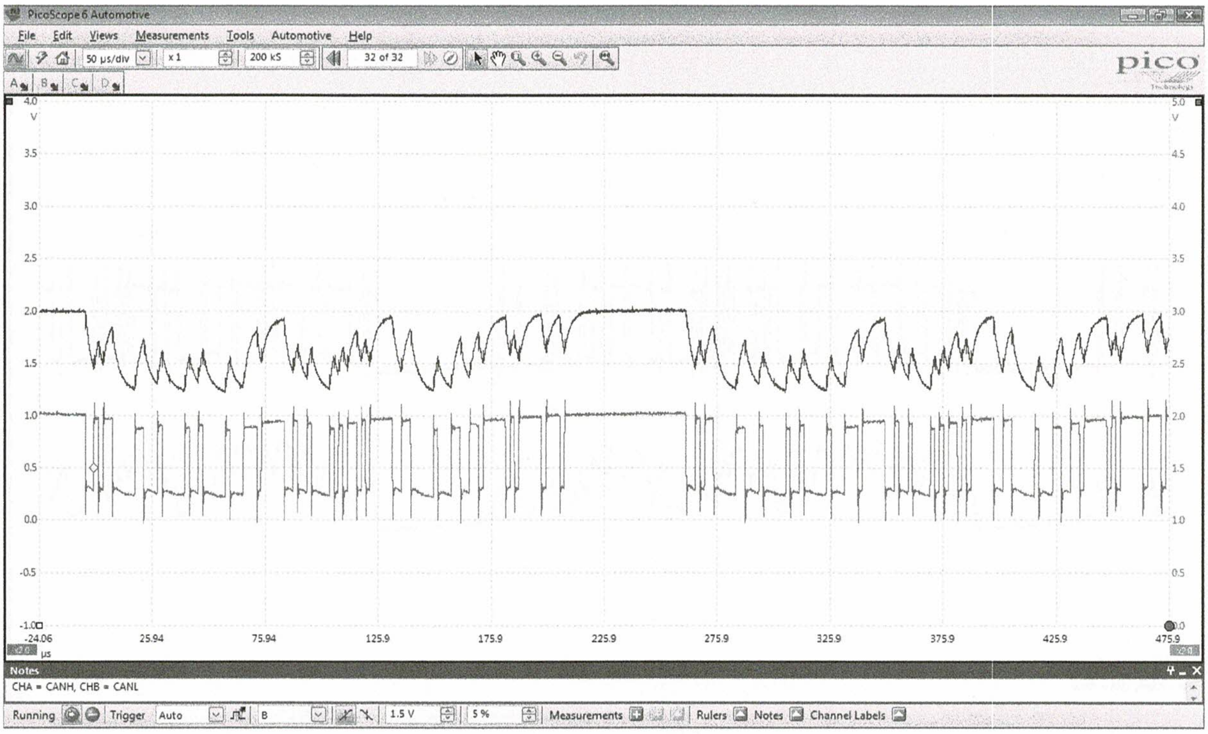
CHA = CANH, CHB = CANL

CAN High is the upper waveform on the left side scale
CAN Low is the lower waveform on the right side scale

CAN Bus uses a floating ground. This means that the ground circuit for the Transceivers is not connected to the chassis of the vehicle. The purpose of this design is that all Nodes do not require a common ground point and helps to isolate the circuit from interference. However, it also causes a fault on one side of the CAN Bus to cause a 'shift' on the other side of the circuit. This is evident on almost all CAN Bus faults. In this image you can see that the OPEN circuit on the CAN-Low has caused the CAN-High, OFF (IDLE) voltage to 'shift' from 2.5 Volts to 3.0 Volts. There is no fault on the high side.

WAVEFORM EXAMPLES continued...

CAN High OPEN Circuit


PicoScope 6 Automotive
File Edit Views Measurements Tools Automotive Help
50 µs/div
x 1
200 kS
32 of 32
pico
A B C D
4.0 V
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
5.0 V
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-24.06 µs
25.94
75.94
125.9
175.9
225.9
275.9
325.9
375.9
425.9
475.9
Notes
Running
Trigger Auto
B
1.5 V
5 %
Measurements
Rulers
Notes
Channel Labels

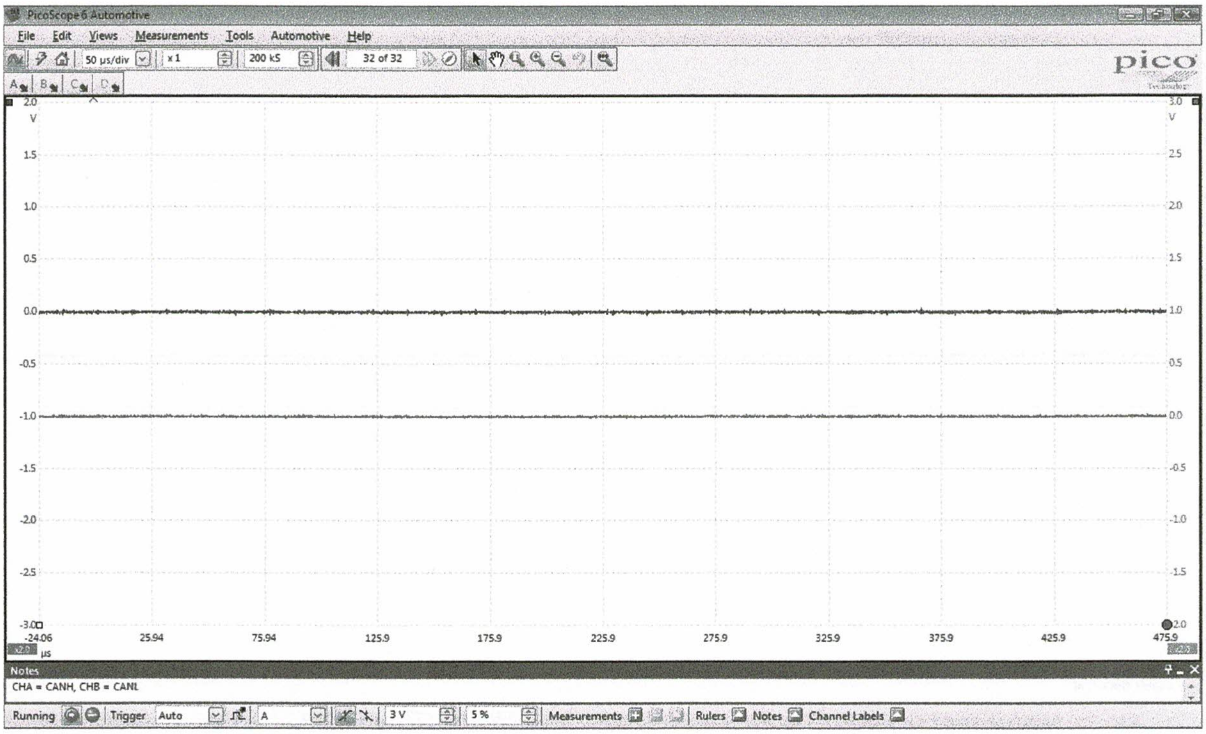
CHA = CANH, CHB = CANL

CAN High is the upper waveform on the left side scale
CAN Low is the lower waveform on the right side scale

CAN Bus uses a floating ground. This means that the ground circuit for the Transceivers is not connected to the chassis of the vehicle. The purpose of this design is that all Nodes do not require a common ground point and helps to isolate the circuit from interference. However, it also causes a fault on one side of the CAN Bus to cause a ‘shift’ on the other side of the circuit. This is evident on almost all CAN Bus faults. In this image you can see that the OPEN circuit on the CAN-High has caused the CAN-Low side OFF(IDLE) voltage to ‘shift’ from 2.5 Volts to 2.0 Volts. There is no fault on the low side.

WAVEFORM EXAMPLES continued...

CAN High and Low OPEN Circuit


PicoScope 6 Automotive
File Edit Views Measurements Tools Automotive Help
50 µs/div
x1
200 kS
32 of 32
pico
2.0 V
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
3.0 V
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-24.06
25.94
75.94
125.9
175.9
225.9
275.9
325.9
375.9
425.9
475.9
µs
Notes
Running
Trigger Auto
A
3 V
5 %
Measurements
Rulers
Notes
Channel Labels

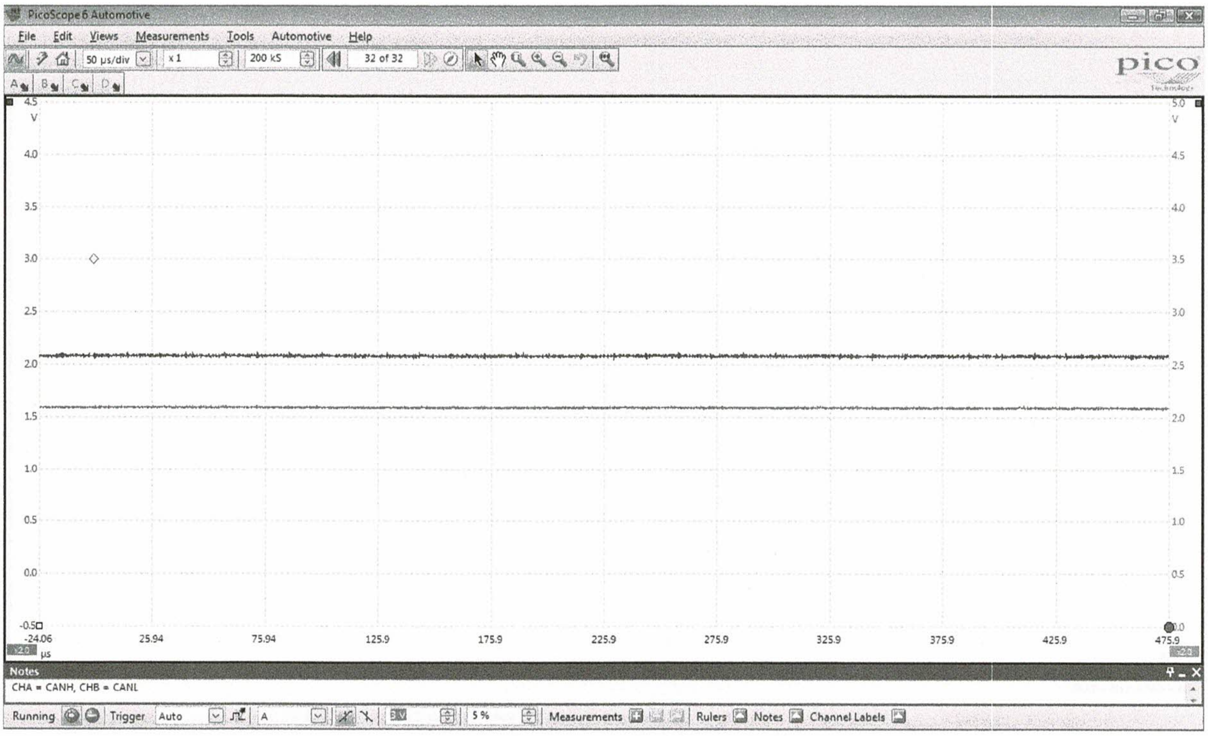
CHA = CANH, CHB = CANL

CAN High is the upper waveform on the left side scale
CAN Low is the lower waveform on the right side scale

This example shows that with both circuits open both Bus lines are at 0.0 Volts

WAVEFORM EXAMPLES continued...

CAN High and Low Short Circuit


PicoScope6 Automotive
File
Edit
Views
Measurements
Tools
Automotive
Help
50 µs/div
x 1
200 kS
32 of 32
pico
A
B
C
D
4.5
V
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
5.0
V
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-24.06
25.94
75.94
125.9
175.9
225.9
275.9
325.9
375.9
425.9
475.9
µs
Notes
Running
Trigger
Auto
A
5 %
Measurements
Rulers
Notes
Channel Labels

CHA = CANH, CHB = CANL

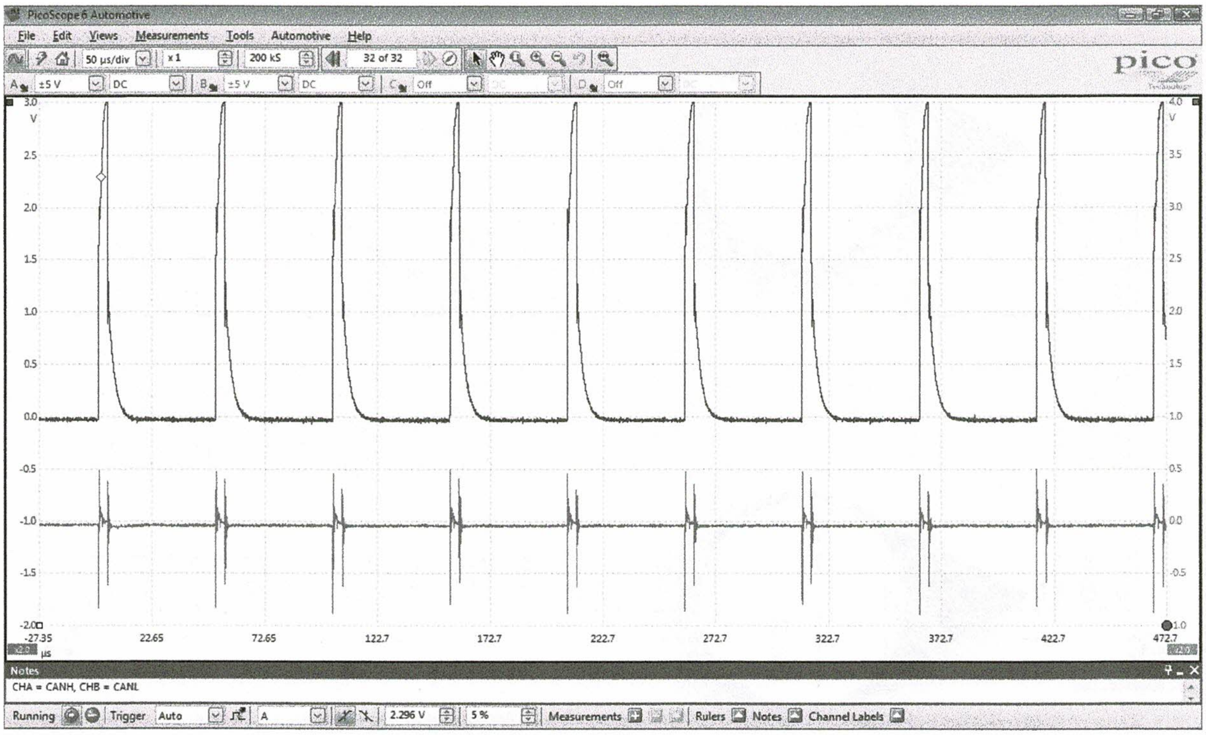
CAN High is the upper waveform on the left side scale
CAN Low is the lower waveform on the right side scale

This example also has two flat lines but the key difference is that shorting the CAN High and Low together has caused the voltages to be fixed.

- CAN High fixed at 2.1 Volts in this example
- CAN Low fixed at 2.1 Volts in this example

WAVEFORM EXAMPLES continued...

CAN Low SHORT to GROUND


PicoScope 6 Automotive
File
Edit
Views
Measurements
Tools
Automotive
Help
pico
3.0 V
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
4.0 V
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-27.35 µs
22.65
72.65
122.7
172.7
222.7
272.7
322.7
372.7
422.7
472.7
Measurements
Rulers
Notes
Channel Labels

50 µs/div
x 1
200 kS
32 of 32
A ±5 V DC
B ±5 V DC
C Off
D Off

Notes
CHA = CANH, CHB = CANL

Running
Trigger Auto
A
2.296 V
5 %

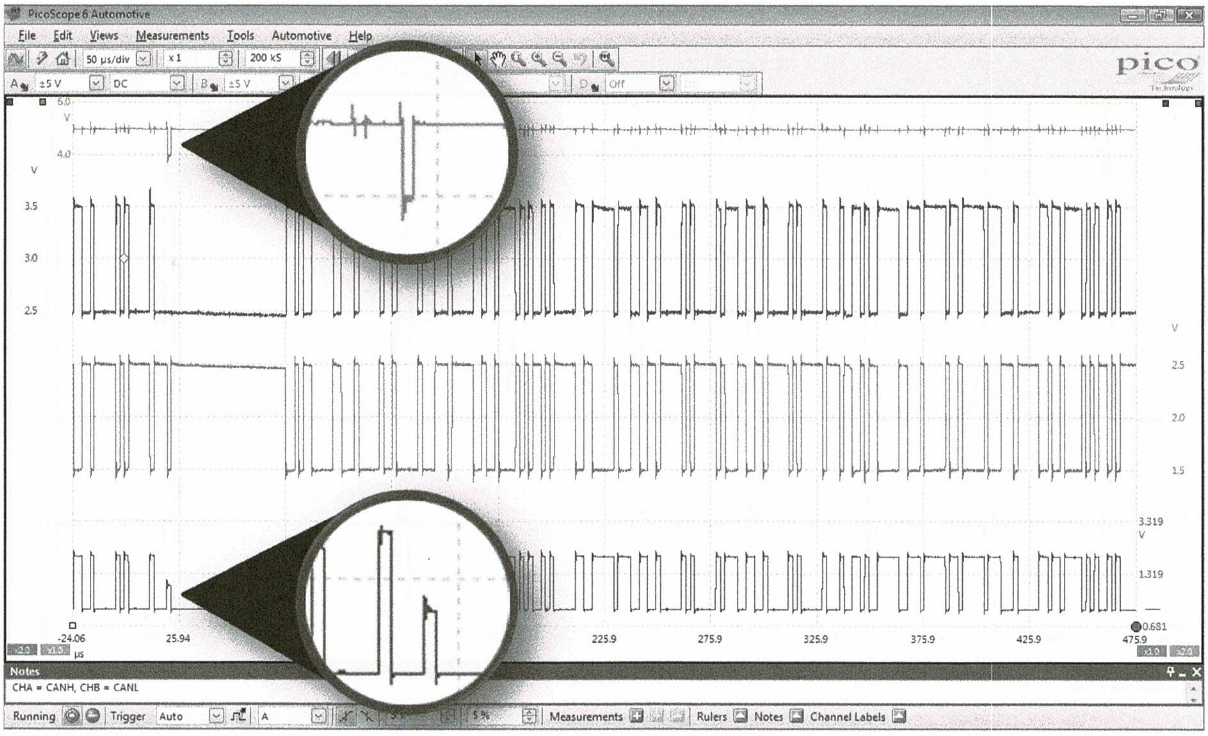
CAN High is the upper waveform on the left side scale
CAN Low is the lower waveform on the right side scale

The CAN controllers have identified that a significant fault exists and are only sending ‘pings’ to check the network for a response. Some vehicles will send these test pings for a specific amount of time before putting the CAN Bus into Sleep Mode, others like this vehicle continue to send the test pings.

Again, the floating ground is evident on the shorted low bus line. If the circuit was chassis grounded the CAN-Low would be a fixed line on 0.0 Volts.

WAVEFORM EXAMPLES continued...

Corrupted CAN message


PicoScope 6 Automotive
File Edit Views Measurements Tools Automotive Help
50 µs/div
x 1
200 kS
pico
A ±5 V DC
B ±5 V
D Off
6.0
V
4.0
3.5
3.0
2.5
2.5
2.0
1.5
3.319
V
1.319
0.681
-24.06
µs
25.94
225.9
275.9
325.9
375.9
425.9
475.9
Notes
Running
Trigger Auto
A
5 %
Measurements
Rulers
Notes
Channel Labels

CHA = CANH, CHB = CANL

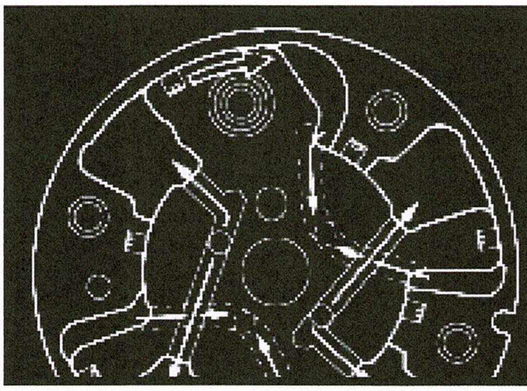
Math Channel A + B is the upper waveform on the adjacent left side scale
CAN High is the upper centre waveform on the adjacent left side scale
CAN Low is the lower centre waveform on the adjacent right side scale
Math Channel A - B is the lower waveform on the adjacent right side scale

The diagram above shows how using math channels on an oscilloscope makes picking CAN Bus errors and/or corruption easy. If you look closely, the last pulse of CAN-Low is missing on CAN-High.

The Math Chanel A + B now shows a deviation from 5 Volts

The Math Channel A - B shows the last pulse at 1.0 Volts instead of 2.0 Volts

This example shows the communication error at the end of a sequence, if it was in the middle of a sequence it would be much harder to spot with the assistance of the Math Channel feature.



Section ii

VVT Fault Diagnosis

CONTENTS

OVERVIEW 36

OIL CONTROL VALVE 38

HYDRAULIC PHASER 39

OPERATION 40

FAILURE TYPES 42
Contaminated and sticking Oil Control Valve 42
Blocked Oil Control Valve Filter/s 43
Solenoid Coil failure of the Oil Control Valve 44
Lack of Engine Oil Pressure 45
Phaser wear and/or failure 46

FUTURE TECHNOLOGY 48

OVERVIEW

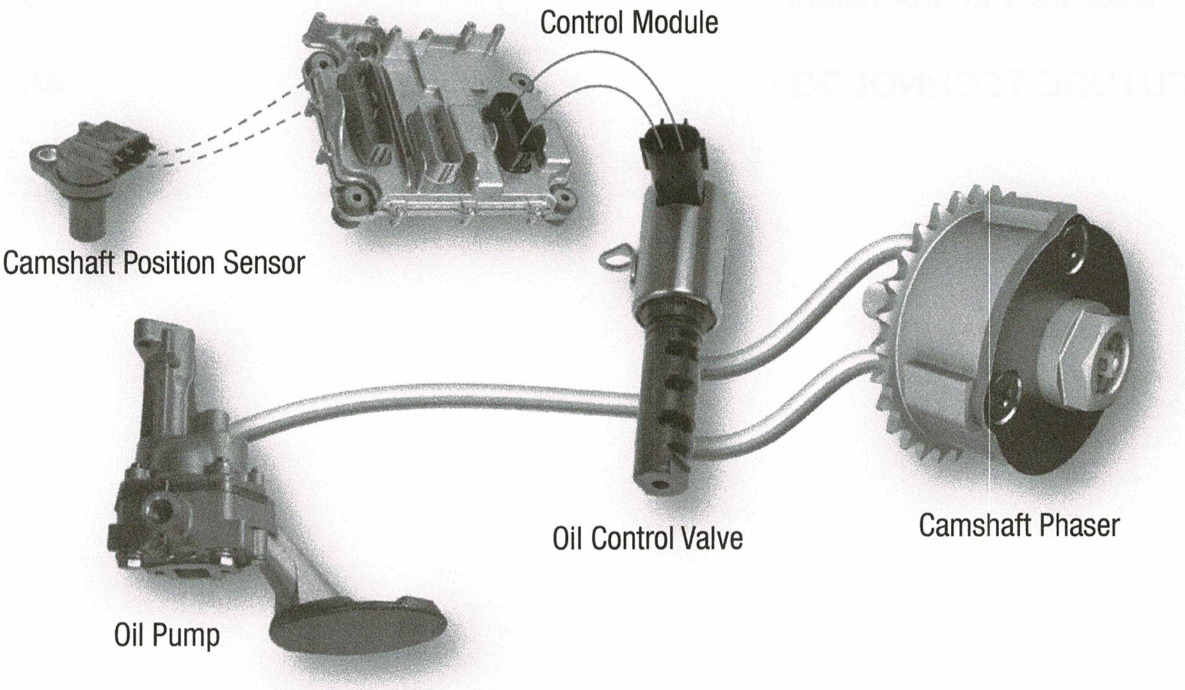
Variable Valve Timing (VVT) is also commonly referred to as Variable Camshaft Timing (VCT), as well as a large variety of other variants of similar meaning and swag of OE marketing names like Porsche's VarioCam!

Prior to the mass acceptance of VVT systems, camshaft profiles were always a compromise between high speed and low speed performance. VVT has allowed for optimal valve timing to be achieved under most conditions.
The benefits of VVT on petrol engines include:

- Improved idle quality
- Improved fuel economy
- Increased power and torque
- Reduced exhaust emissions

In 2013 Mitsubishi released the first mass production diesel passenger car to feature VVT to the Australian and New Zealand markets, in the form of their Mitsubishi Innovative Valve-timing Electronic Control (MIVEC) system. The 4N1# series engines feature ultra low compression ratios which claims to reduce fuel economy by up to 25% over previous non-MIVEC engines. Low compression causes low temperature instability in diesel engines which is where Mitsubishi utilises camshaft advance phasing to increase the effective cold compression ratio.

While there have been a few variations on the design and function of the VVT system it has been the Hydraulic Phaser system that has proven to be the most reliable and has become the system used by almost all manufacturers.
The system consists of:



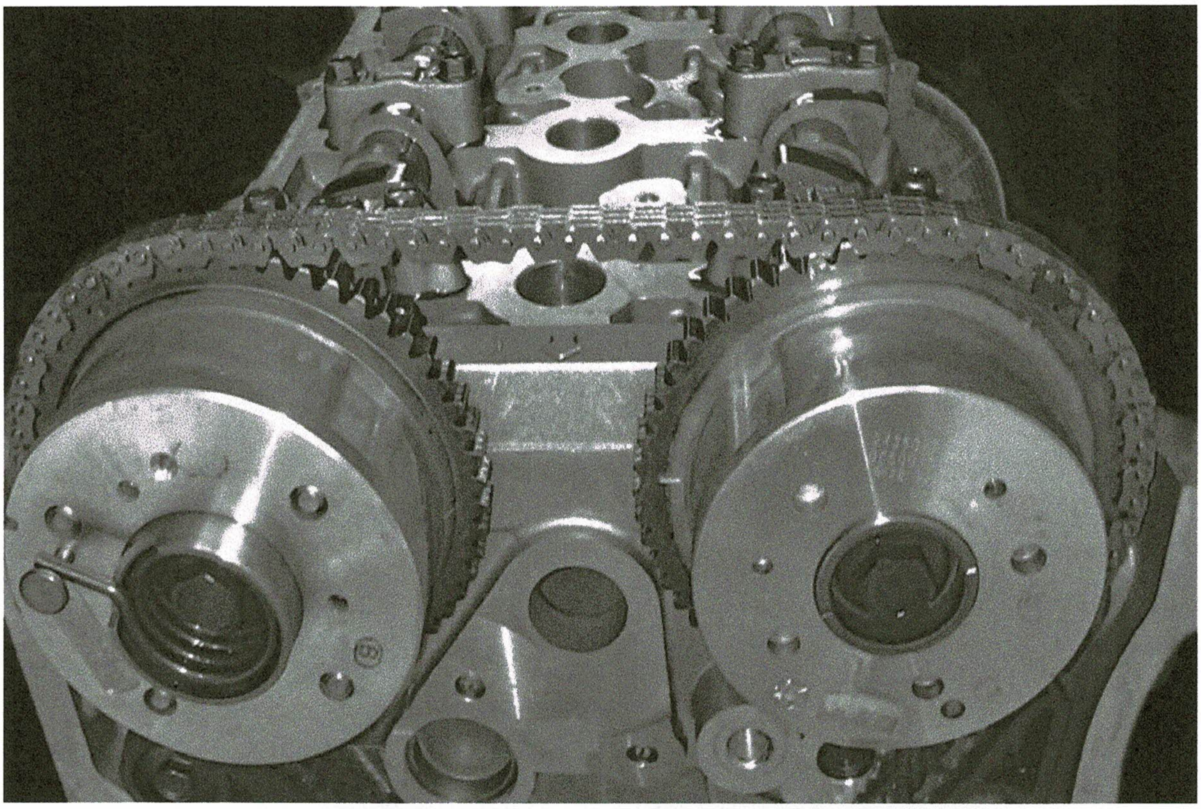
VVT is still a relatively new technology, this may be overwhelming to some technicians. But in reality the VVT system is surprisingly simple.

OVERVIEW continued...

There are four configurations in which the Hydraulic Phaser VVT system is offered:

1. SOHC - Uncommon in AU and NZ markets (mainly US derived SOHC V8's)
2. DOHC with Inlet VVT
3. DOHC with Dual VVT
4. DOHC with Dual Independent VVT

Configurations 2, 3 and 4 have evolved consecutively with the vast majority of VVT systems now of the Dual Independent variety. One of the key factors is that it allows for the removal of the Exhaust Gas Recirculation (EGR) System, EGR is achieved by increasing the valve overlap to achieve what is referred to as Internal EGR.



DOHC Dual VVT system with return spring on exhaust phaser.

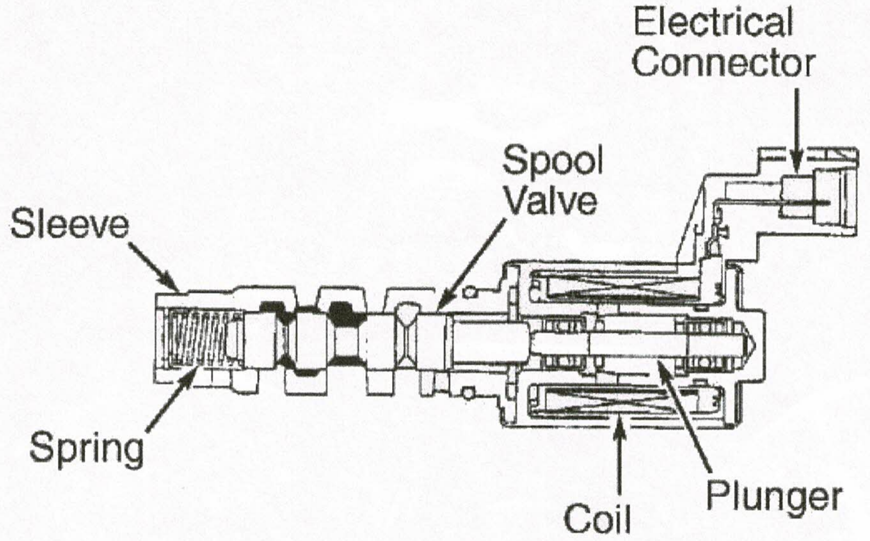
Caution: *As the VVT system is hydraulically controlled with the same engine oil that lubricates the engine, it is essential that:*

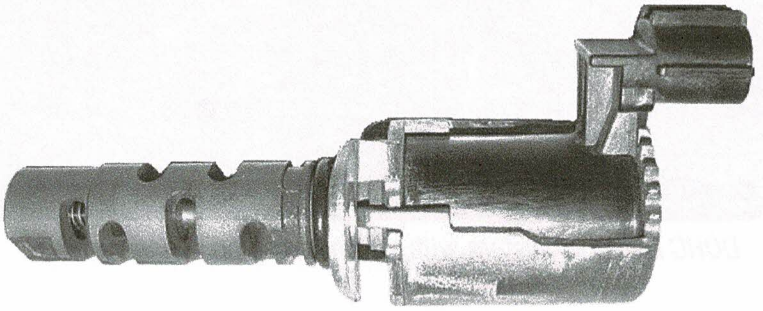
> The oil viscosity is correct (eg: 5W-30)
> The oil grade is correct (eg: ACEA A3)
> The oil is changed regularly and on time!

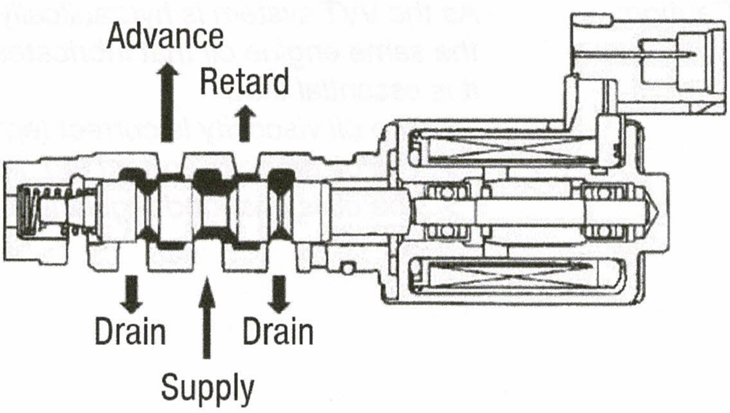
OIL CONTROL VALVE

The Oil Control Valve is made up of a Duty Cycle controlled solenoid attached to a Spool Valve. The PCM will use the Oil Control Valve to control oil flow to the Camshaft Phaser.

Oil Control Valves are highly susceptible to contamination primarily from insufficient oil changes. Contamination may block the filter screens in the inlet feeds or particles may jam the Spool Valve. In many cases it may be possible to clean the filters and valves but check that cleaning is an economical choice. Filter screens can be very cheap (less than A$10) and a freed spool valve might have a limited life due to scoring in the bore caused by the grit that jammed it.

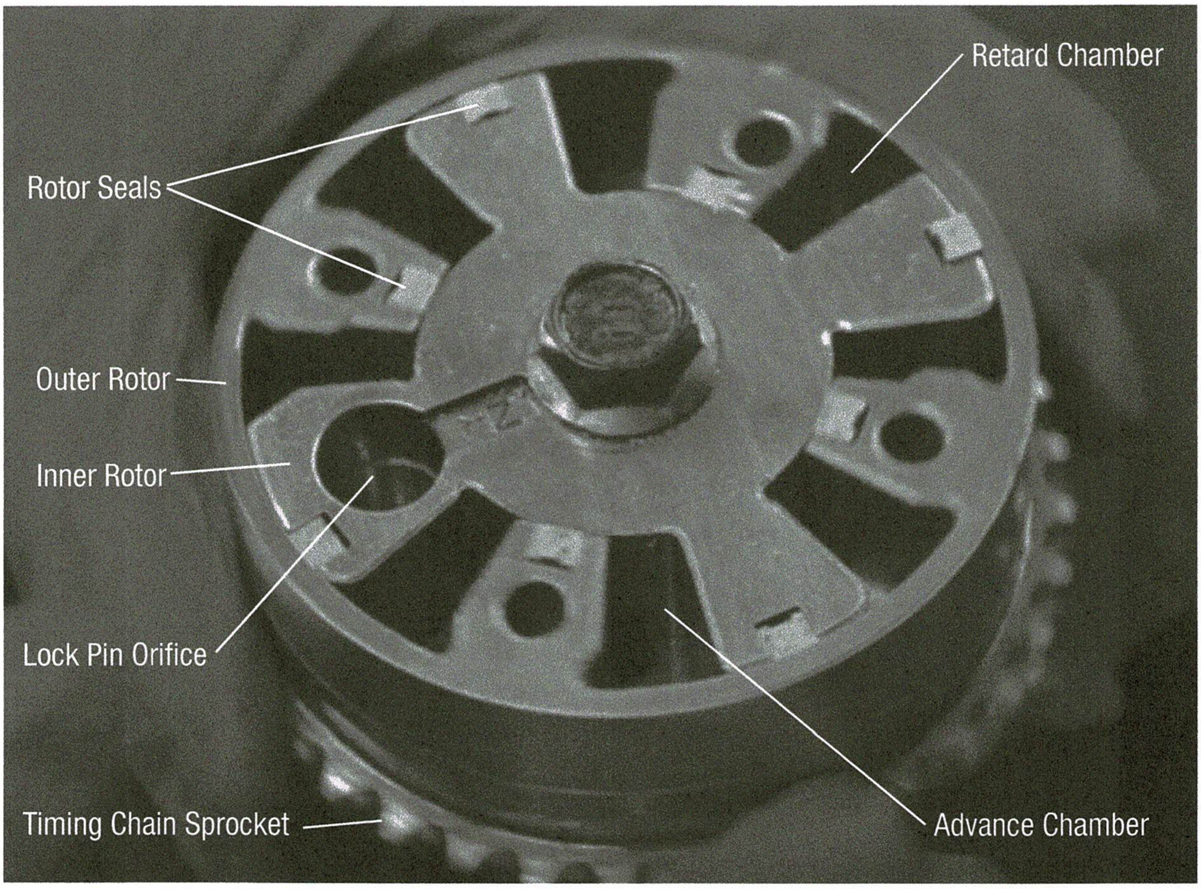

Electrical Connector
Spool Valve
Sleeve
Spring
Coil
Plunger




Advance
Retard
Drain
Drain
Supply

HYDRAULIC PHASER

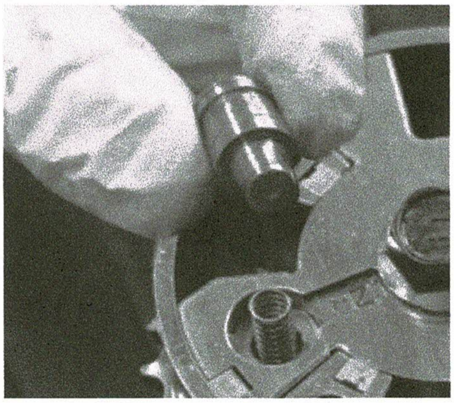
The Hydraulic Phaser provides a variable connection between the Drive Sprocket and the Camshaft. It is controlled with high pressure engine oil by the PCM via the Oil Control Valve. The Hydraulic Phaser contains the following components:



- When the oil pressure is greater in the Advance Chamber the Camshaft will be advanced in relation to the position of the sprocket
- When the oil pressure is equal in both chambers the Camshaft position will be held
- When the oil pressure is greater in the Retard Chamber the Camshaft will be retarded in relation to the position of the sprocket.
- When there is insufficient oil pressure the Locking Pin holds the Phaser in the retarded position.

  For Intake Phasers the Valve Springs and Followers provide enough resistance to move the Phaser back to its locking position.

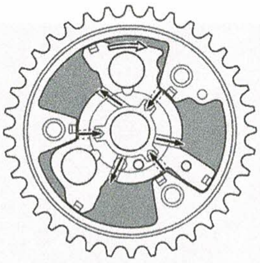
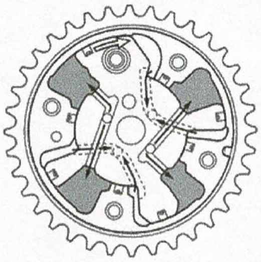
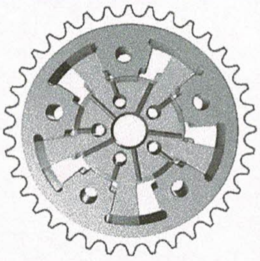
  For Exhaust Phasers, the locked position is usually in the advanced position so a spring is usually employed to return the Phaser to its locking position.



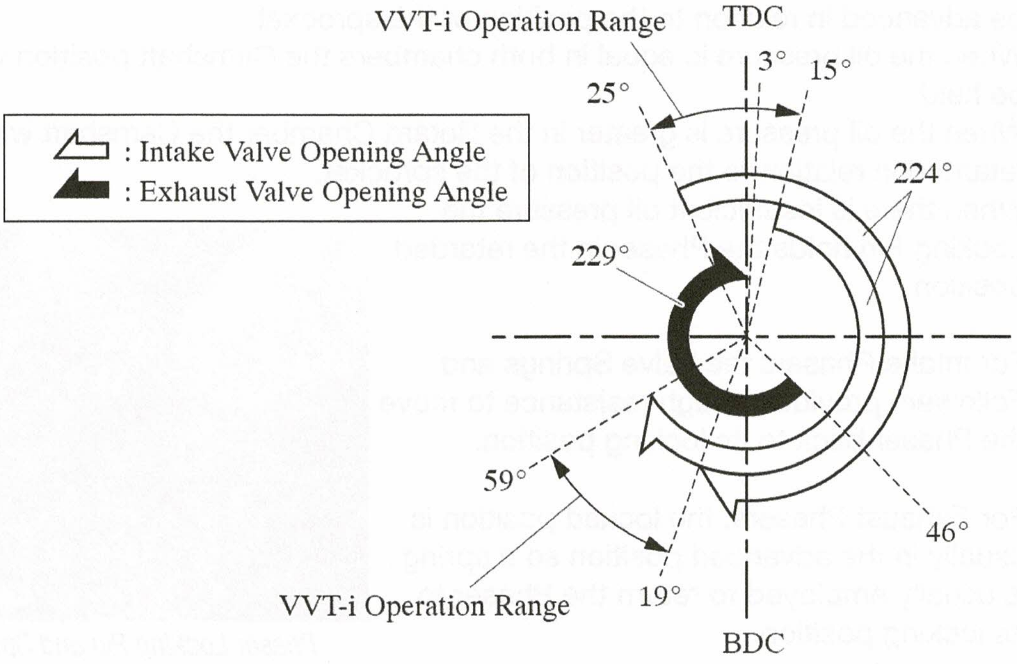
Phaser Locking Pin and Spring

OPERATION

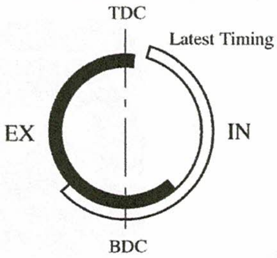
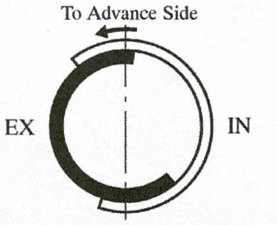
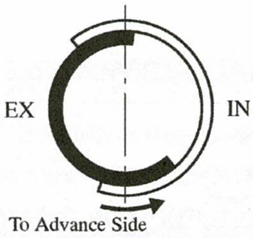
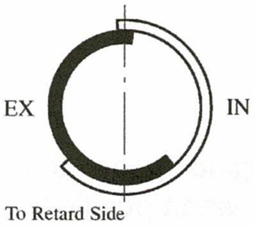
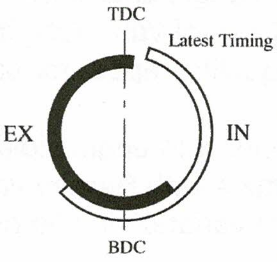
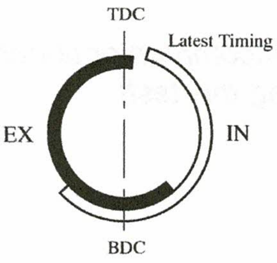
The design of the Phaser sets out the maximum Advance/Retard variation. Less Vanes allow for a greater variation spread but reduces the hydraulic advantage:

	3 Vane Phaser	Toyota Atkinson Cycle engines (Hybrid engines) >80° variation Other small engines >60°variation
	4 Vane Phaser	Most engines >50° variation
	5 Vane Phaser	Ford V8 engines >30° variation

The following information is for a Toyota 2UZ engine, it is provided here to show how much variation the Phaser has and how that adjustment is utilised:

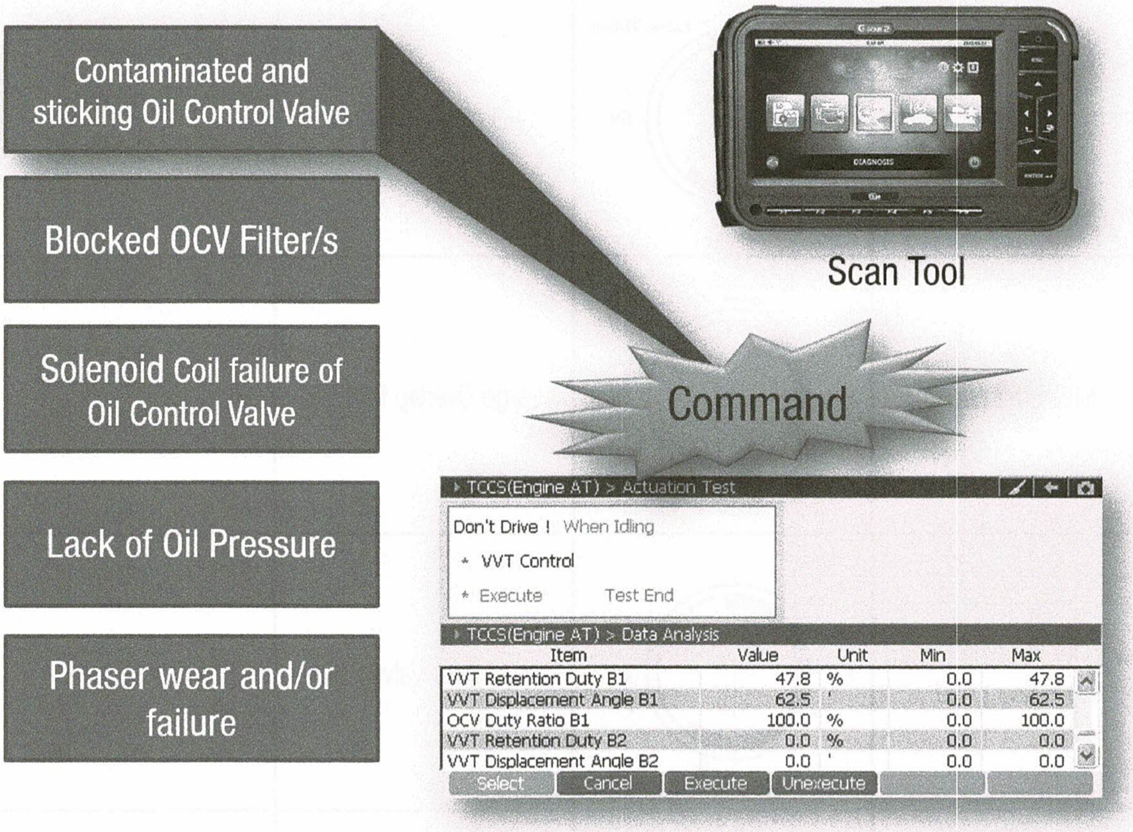

VVT-i Operation Range
TDC
3°
15°
25°
⇦ : Intake Valve Opening Angle
⬅ : Exhaust Valve Opening Angle
224°
229°
59°
46°
19°
VVT-i Operation Range
BDC

OPERATION continued...

Operating State	Position	Objective	Effect
Idle	 TDC Latest Timing EX IN BDC	Eliminate Overlap	Stable Idle Fuel Reduction
Light Load			
Medium Load	 To Advance Side EX IN	Large Overlap for EGR	Fuel Reduction NOx Reduction
Low to Mid Engine Speed and Heavy Load	 EX IN To Advance Side	Close Intake Valves earlier	Increase torque
High Engine Speed and Heavy Load	 EX IN To Retard Side	Delay closing of the Intake Valves	Increase Power
Engine Cold	 TDC Latest Timing EX IN BDC	Eliminate Overlap	Stable Idle Fuel Reduction
At Startup	 TDC Latest Timing EX IN BDC	Eliminate Overlap	Stability
On Shutdown			

FAILURE TYPES

Contaminated and sticking Oil Control Valve



Contaminated and sticking Oil Control Valve

Blocked OCV Filter/s

Solenoid Coil failure of Oil Control Valve

Lack of Oil Pressure

Phaser wear and/or failure

Don't Drive ! When Idling

- VVT Control
- Execute Test End

TCCS(Engine AT) > Data Analysis

Item	Value	Unit	Min	Max
VVT Retention Duty B1	47.8	%	0.0	47.8
VVT Displacement Angle B1	62.5	'	0.0	62.5
OCV Duty Ratio B1	100.0	%	0.0	100.0
VVT Retention Duty B2	0.0	%	0.0	0.0
VVT Displacement Angle B2	0.0	'	0.0	0.0

Procedure:

1. Ignition ON, check DTC's
   Always address other DTC's first!
   Values required for VVT operation – engine speed, air mass value, intake air temp, throttle angle, coolant temp, camshaft position…
2. Live Data, check desired angle, actual angle and/or variation angle
3. With engine idling command the Oil Control Valve ON, there should be a substantial negative variation in idle quality, repeat for each Oil Control Valve or Phaser
4. If you do not have a command function, with engine idling disconnect each Oil Control Valve connector and energise with Battery volts (max 5 seconds), there should be a substantial negative variation in idle quality, repeat for each Oil Control Valve or Phaser.

Note: *It is not uncommon or abnormal for the engine to stall during this test!*

FAILURE TYPES continued...

Blocked Oil Control Valve Filter/s

Contaminated and sticking Oil Control Valve

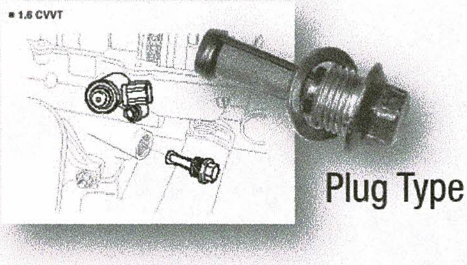
Blocked OCV Filter/s

Solenoid Coil failure of Oil Control Valve

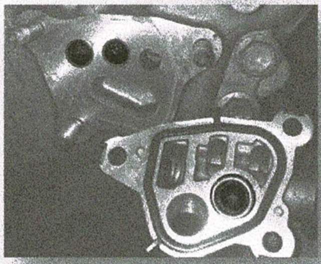
Lack of Oil Pressure

Phaser wear and/or failure

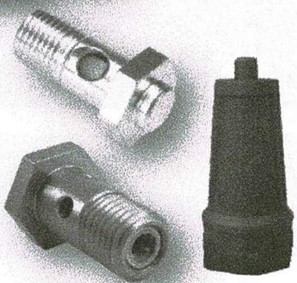
Inspect



Plug Type



Insert Type



Banjo Type

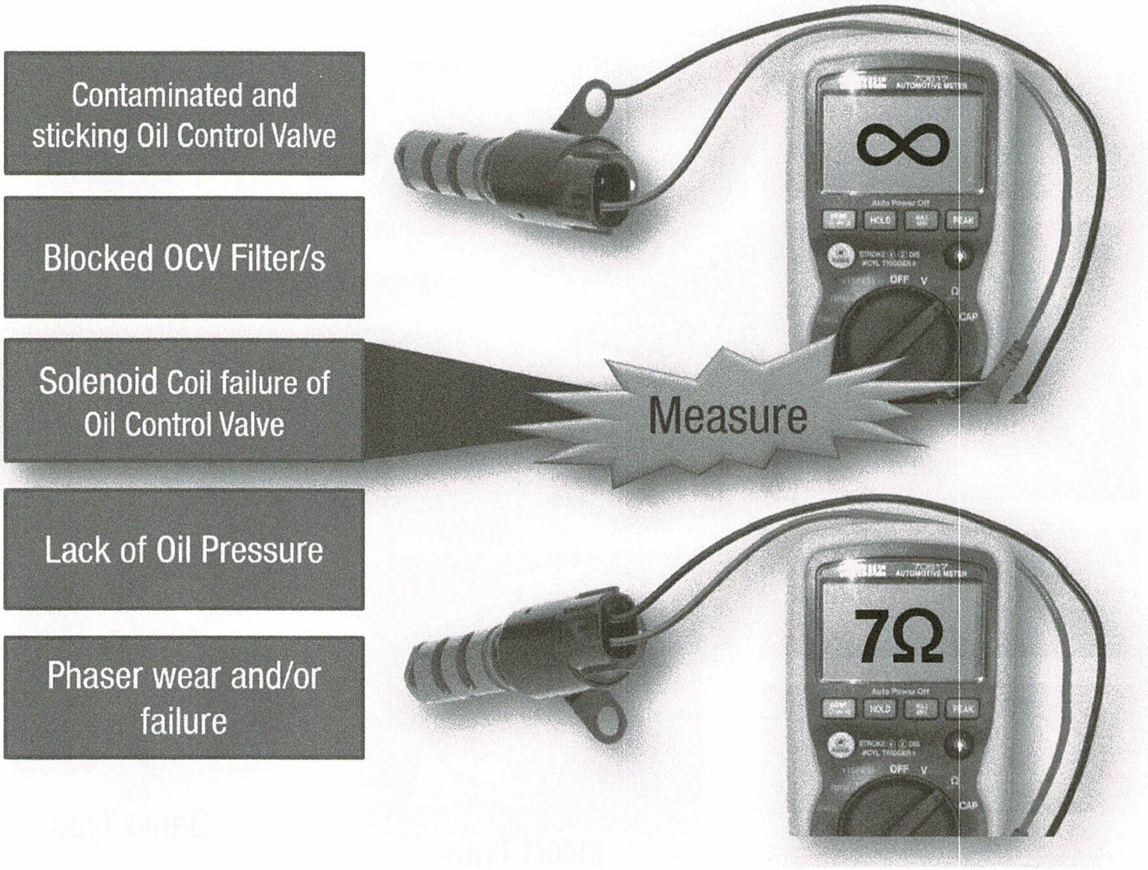
Procedure:

1. Refer to the specific vehicles service information to locate the filter/s
2. Remove the filter/s and inspect
3. Clean or replace the filter/s as required

Caution: *All filters are sealed with either a gasket, o-ring or washer, ensure that new seals are fitted to prevent oil leaks!*

FAILURE TYPES continued...

Solenoid Coil failure of the Oil Control Valve


Contaminated and sticking Oil Control Valve
Blocked OCV Filter/s
Solenoid Coil failure of Oil Control Valve
Lack of Oil Pressure
Phaser wear and/or failure
Measure
∞
7Ω

Procedure:

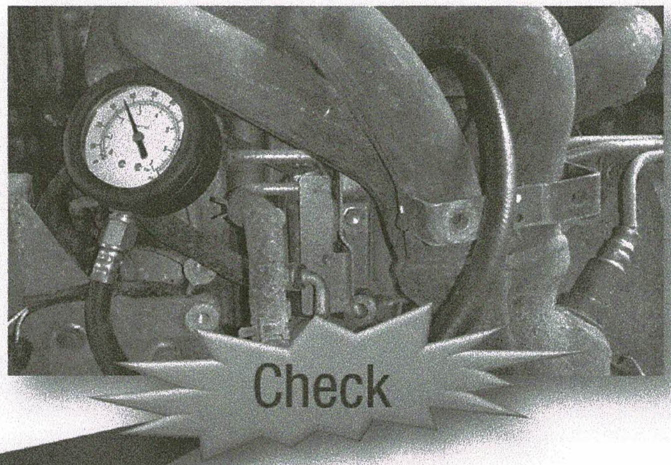
1. Ignition OFF
2. Disconnect the Oil Control Valve electrical connector
3. Measure the resistance between either terminal and the body of the Oil Control Valve, should be Infinite Ohms
4. Measure the resistance between the two pins of the Oil Control Valve, as a very generalised specification 6 to 8Ω is usually close (Always use factory specs where possible)

Note: *If the vehicle being tested has Dual VVT, compare both Oil Control Valves. If the valves are identical (many are), you can even try swapping the valves. If the fault follows the Oil Control Valve, your diagnosis is done!*

FAILURE TYPES continued...

Lack of Engine Oil Pressure

- Contaminated and sticking Oil Control Valve
- Blocked OCV Filter/s
- Solenoid Coil failure of Oil Control Valve
- Lack of Oil Pressure
- Phaser wear and/or failure



Condition	Oil Pressure	
Idle	>120kPa	>18psi
4,000 RPM	>270kPa	>40psi
Maximum	≈350kPa	≈50psi

The phasers will not function without sufficient oil pressure. Lack of oil pressure can be caused by blocked screens or a lack of oil pressure being supplied by the oil pump. Some systems that have pipes connecting the OCV with banjo type unions can have adapters that allows monitoring of the exact pressure being supplied to the Phaser. However, most newer vehicles now have the oil feeds integrated into the Cylinder Head and therefore the only inspection procedure is to physically inspect the Filter Screens and measure the oil pressure at the Oil Pressure Switch.

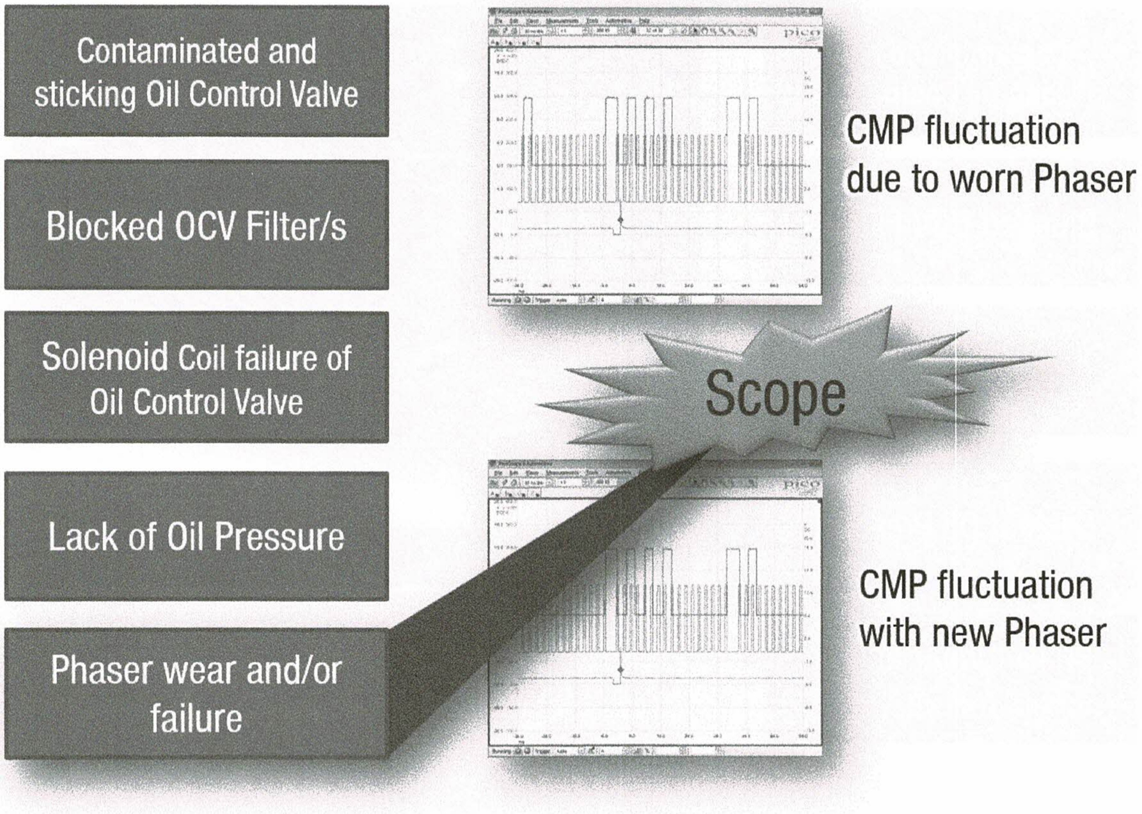
Procedure:

1. Ignition OFF
2. Remove the Oil Pressure Switch
3. Install an Oil Pressure Gauge
4. Measure the engine oil pressure, as a general rule approximately:
5. 130kPa (19psi) or more at Idle
   270kPa (40psi) is a typical maximum running pressure at around 4,000rpm
   350kPa (50psi) will normally open the Safety Bypass Valve

Note: *After inspecting the oil pressure, many modern vehicles will require the DTC's to be cleared as the PCM monitors the oil pressure!*

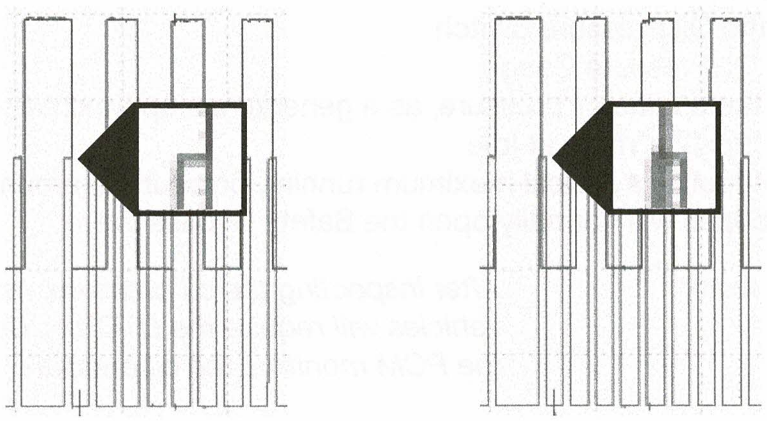
FAILURE TYPES continued...

Phaser wear and/or failure


Contaminated and sticking Oil Control Valve
Blocked OCV Filter/s
Solenoid Coil failure of Oil Control Valve
Lack of Oil Pressure
Phaser wear and/or failure
pico
CMP fluctuation due to worn Phaser
Scope
pico
CMP fluctuation with new Phaser

A noninvasive test usually reduces time and the replacement of ancillary components such as gaskets. One way of testing the phaser for wear without removing the Valve Cover/s is to monitor the variation between Camshaft Position Sensor (CMP) and the Crankshaft Position Sensor (CKP) with the engine idling at normal operating temperature.

The following close-up shows the CMP (upper) waveform moving to the left in relation to the CKP (lower) waveform:



FAILURE TYPES continued...

Oscilloscope Procedure

1. Set collect time frame to 10ms/div
2. Connect Channel A to the CKP sensor signal
3. Set Channel A to the 10 or 20 Volts scale
4. Connect Channel B to the CMP sensor signal
5. Set Channel B to the 10 or 20 Volts scale
6. Connect Channel C to an Injector command (preferably #1 but not essential)
7. Set Channel C to the required scale (100 Volts is typical)
8. Set the Trigger to Channel C > Falling Edge > 5 Volts
   (this holds the waveform, an essential step in this procedure)
9. Monitor the waveform, in the area adjacent to the trigger point the waveforms should stay in sync.

Manual Procedure

1. Remove all parts necessary to remove the Camshaft and Phaser
2. Hold the Camshaft in a Vice with soft jaws
3. Try to rotate the Phaser, if the Locking Pin works it will not move and should have minimal free play
4. Apply 200kPa air pressure to the Advance Oil Feed Hole
   (this should disengage the Locking Pin)
5. Check that the rotation of the Phaser is free and smooth without any looseness or rattling
6. Replace Phaser if any issues are found.

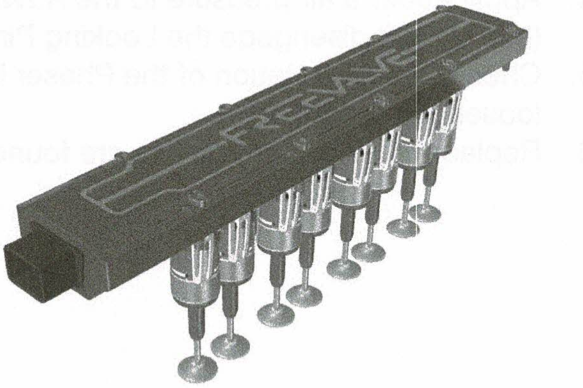
FUTURE TECHNOLOGY

A number of companies are working on engine designs that do not use Camshafts, these are generally referred to as Camless Engines. The Freevalve company (a subsidiary of Koenigsegg) appears to have one of the promising designs.
It is already using this technology in its Hypercars, but claims that this new 4 cylinder engine has been developed for a Chinese passenger car manufacturer (the company has not been disclosed).

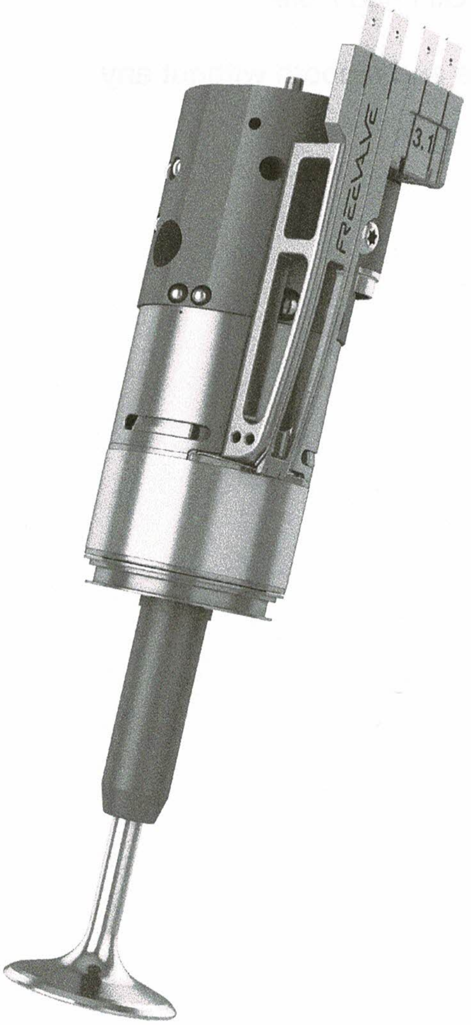
The Camless engine uses electronically controlled, pneumatically actuated solenoids to open and close the valves. Pressurised oil is also fed to the actuators for lubrication purposes. This system offers completely independent valve control for both duration and lift.

Providing the advantages of:

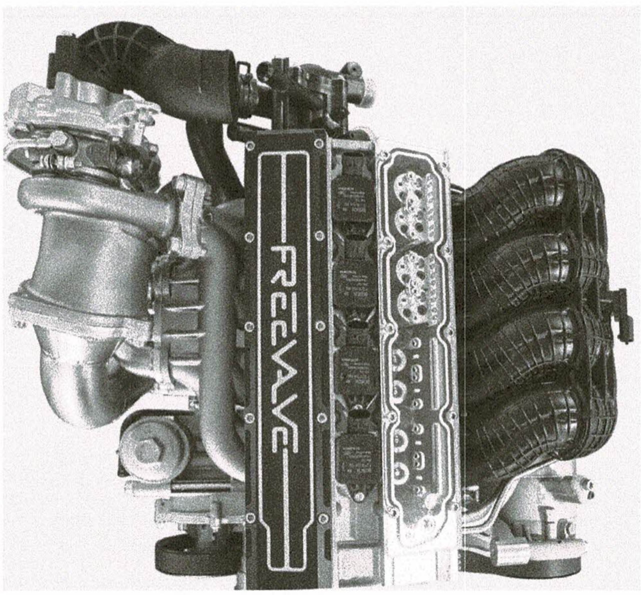
- Variable Valve Timing
- Variable Valve Lift
- Variable Cycle – can operate in normal Otto Cycle as well as Atkinson Cycle
- Enhanced emission control
- Cylinder Deactivation



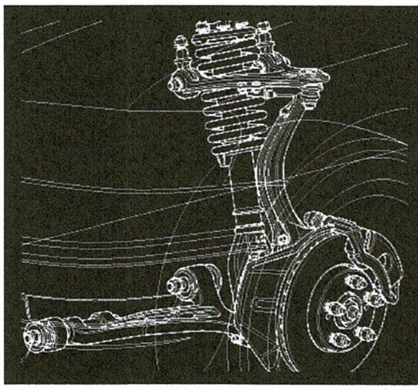
Electronic, Pneumatic and Hydraulic Unit



Electro-Pneumatic Valve Actuator



4 Cylinder Engine with clear Intake Valve Cover



Section iii

Suspension, Advanced Fault Diagnosis

CONTENTS

IDENTIFICATION 50
Critical information: 50
Types of noises: 50
Back in the workshop: 51

INSPECTION 52
Where to put "The Jack" 52
Short Arm Long Arm Suspension 52
MacPherson Strut Suspension 54
Double Wishbone Suspension - Type A 56
Double Wishbone Suspension - Type B 58

DIAGNOSIS 60
Chassis Ear 60
Digital Action Camera 61

MASKING 62

NOTES 62

IDENTIFICATION

Diagnosis MUST begin with identification of the noise:

- Have the customer demonstrate the noise
- If they cannot demonstrate it, suggest they return once they can

Note: *To the technician, a 'noise' may be a trivial matter.*

We (the automotive professional) may see multiple other concerns that may affect the safety or serviceability of the vehicle, that we know should take precedence over the 'noise'.

But to the customer the 'noise' is all they are aware of!

Critical information:

Where – Front, back, left, right…
When – Cold, warm, hot, wet, dry…
How – Cornering, undulation, speed bumps, braking…
Speed – Fast, slow or specific (eg. 60-70km/h)…
Weight – Passengers, luggage, load distribution, fuel level…
Type - How would you describe the noise…

Types of noises:

Knock

- Singular noise
- Usually load bearing

Rattle

- Series of less severe knocks
- Usually non-load bearing

Squeak or Squawk

- Identify direction that causes noise (up-down, left-right)
- Harder surfaces create higher pitch squeak
- Softer surfaces create lower pitch squawk

Creak

- Most evident when frame is twisted (entering driveway on angle)
- Usually frame or trim
- Two surfaces rubbing together

IDENTIFICATION continued...

Back in the workshop:

- Considerable forces may be required to identify fault
- An assistant is often required
- Large pry bars, 500mm multi-grips, soft faced mallets

First piece of diagnostic equipment is a good torch, look for:

Bushings

- Perished, distorted, delaminated or split
- Evidence of rubber rubbing
- Rust may indicate loose fitment
- Polished components around bush

Joints (ball & tie-rod)

- Split boots
- Rust may indicate loose fitment

Bolts and Fixings

Often overlooked an correctly torqued bolt but be the source of a knock. Overtime a rusty witness mark may appear, but not always.

Ensure that all bolts are torqued correctly! This is usually an overlooked component of the scheduled maintenance.

Note: *Some vehicles use Torque To Yield (TTY) bolts, if they come loose they must be replaced. Always check the torque specifications, if they are TTY there should be a note advising so!*

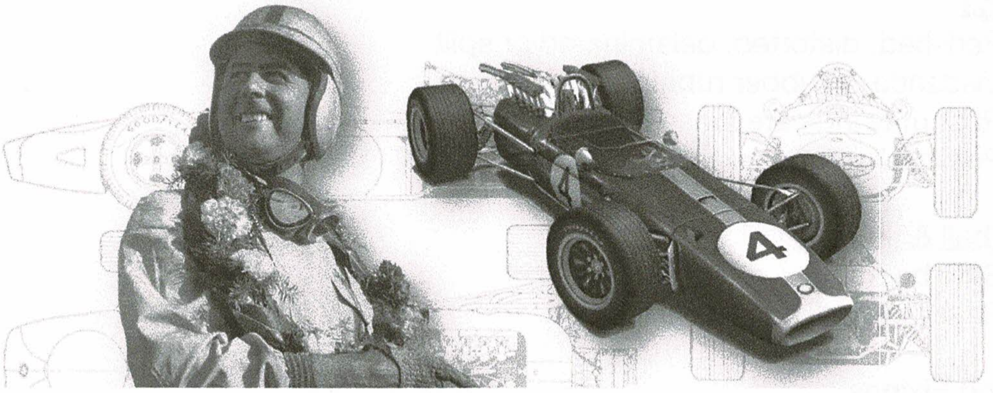
Some Tie Rod End and Ball Joint Pins state angular torque specifications, these are not TTY and the joint can be reused

Caution: *Some Tie Rod End and Ball Joint Pin Nuts are single use, this is because they are self locking by means of thread distortion, when reused they are no longer self locking!*

INSPECTION

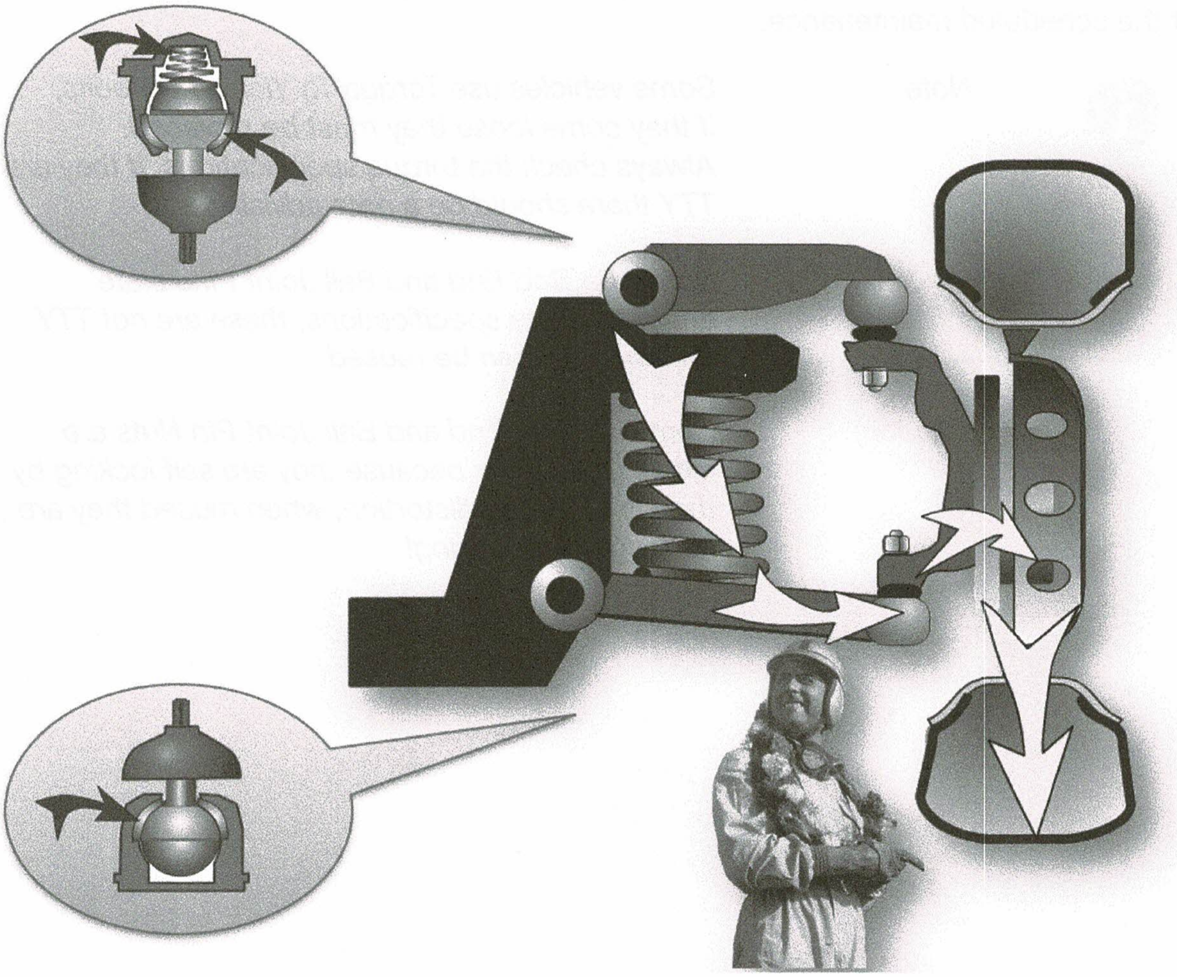
Where to put "The Jack"

I don't know if he knew where to put a Jack (pretty confident that he did) but he sure knew how to drive! Jack Brabham, AU, OBE was born in 1926 and died in 2014. He is Australia's most decorated driver with to many major race wins from 1948 to 1970 to mention. In 1966 he became the only person ever to win the Formula One Championship in a car that he built!



In this section the motorsport legend will show you how to check suspension for wear.

Short Arm Long Arm Suspension



INSPECTION continued...

In Short Arm Long Arm (SLA) Suspension the vehicle load is transferred from the Chassis, through the Spring, the Lower Control Arm, Lower Ball Joint, Steering Knuckle (Stub Axle), to the Wheel. The Lower Control Arm is load carrying, while the Upper Control Arm provides stability.

Lower Ball Joint

The Lower Ball Joint operates in extension (pin is pulled away from the housing), so placing the Jack under the Lower Control Arm forces the Ball Joint Pin downwards. By placing a lever between the ground and the Tyre the Wheel can be lifted to reveal any wear in the Ball Joint.

Upper Ball Joint

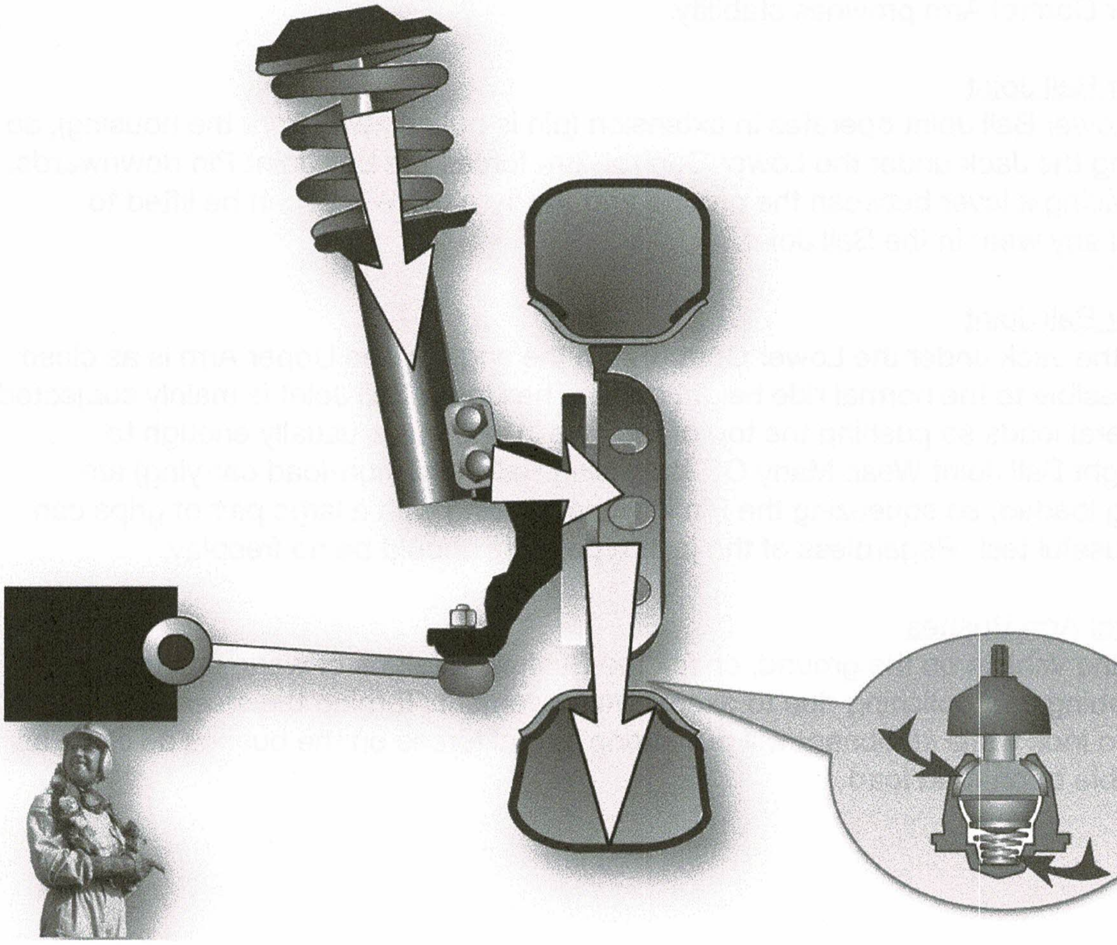
With the Jack under the Lower Control Arm the angle of the Upper Arm is as close as possible to the normal ride height angle. The Upper Ball Joint is mainly subjected to lateral loads so pushing the top of the Tyre in and out is usually enough to highlight Ball Joint Wear. Many OE stabilising Ball Joint (non-load carrying) are spring loaded, so squeezing the Pin into the housing with a large pair of grips can be a useful test. Regardless of the joint type there should be no freeplay.

Control Arm Bushes

With the vehicle on the ground, check the Bushes for signs of wear, crack/tears or rubbing and polishing due to excessive movement. Turning the steering from lock to lock while stationary will put strong lateral forces on the bushes as close as possible to on road load.

INSPECTION continued...

MacPherson Strut Suspension



MacPherson Strut suspension systems have become the most common due to its simplicity and its single upper mounting which provides more width in the Engine Bay (a necessity for vehicles with transverse engines). It is cheaper to design and manufacture, but offers less control of Camber during suspension travel. The vehicle load is transferred from the Chassis, through the Spring, the Strut, Steering Knuckle (Stub Axle), to the Wheel. The Lower Control Arm provides stability and the Radius Arm (not shown) controls the Caster Angle.

Lower Ball Joint

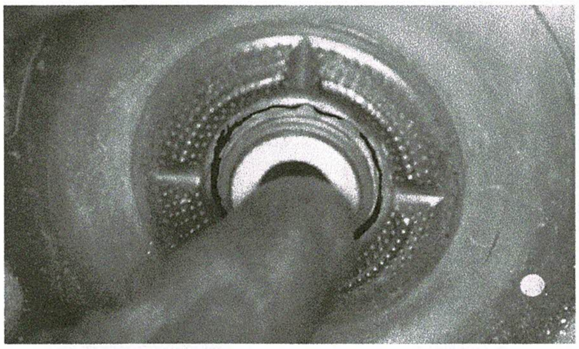
The Low Ball Joint

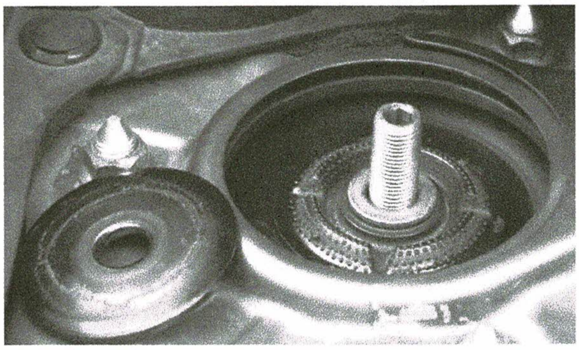
Many OE stabilising Ball Joint (non-load carrying) are spring loaded, so squeezing the Pin into the housing with a large pair of grips can be a useful test. Regardless of the joint type there should be no freeplay.

INSPECTION continued...

Upper Strut Mount

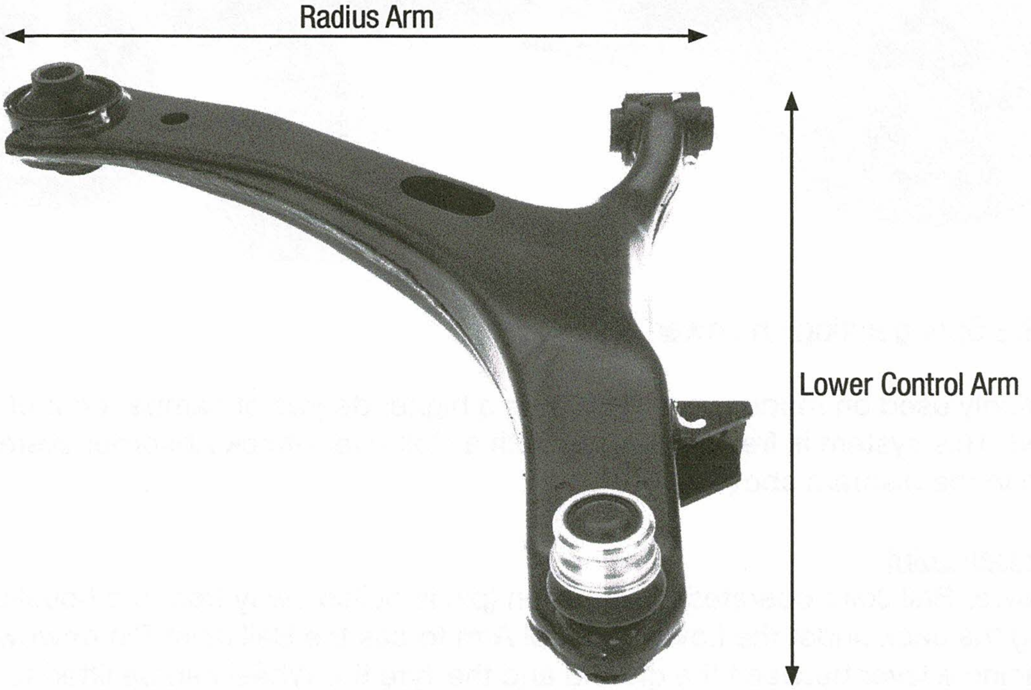
With the vehicle on raised and the suspension hanging, grab both sides of the highest spring coil you can safely reach (without squashing hand between spring and tower). In addition to a visual inspection, shake coil up and down vigorously, there should be no freeplay, movement or noise.





Radius Arm Bushes

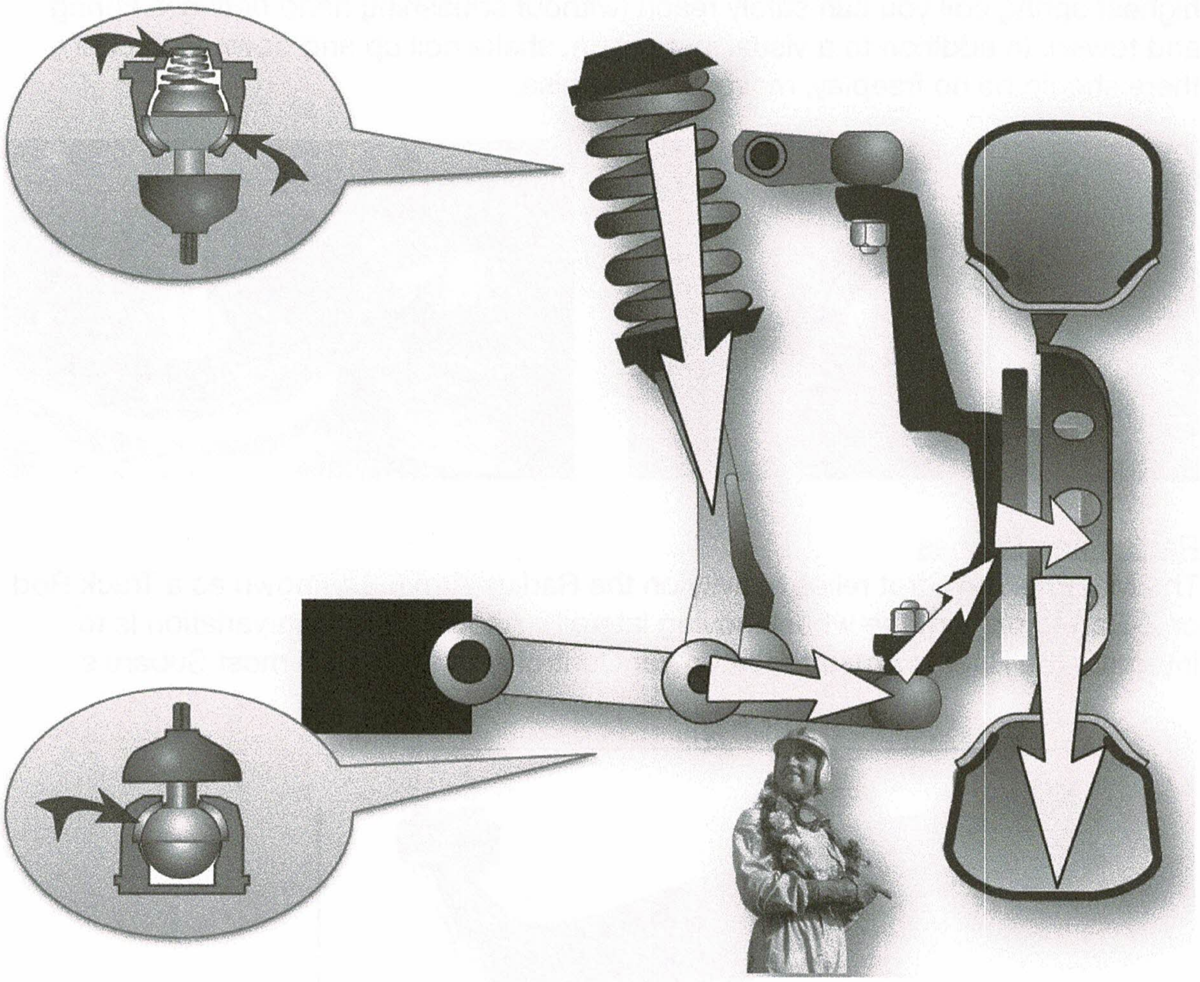
The MacPherson Strut relies heavily on the Radius Arm (also known as a Track Rod or Z-Bar) to prevent the wheel moving laterally. Another common variation is to integrate the Radius Arm into the Lower Control Arm such as in most Subaru's.



Radius Arm Bushes can be difficult prove out as the cause of a noise, this is because the forces that are applied on the road are very difficult to recreate in the workshop. A visual inspection is very important, outside of obvious cracks in the bushings, look for scuff marks that indicate excessive movement. Chassis Ears should pinpoint the cause, also a digital action camera (such as a GoPro) can be helpful if the noise is of to lower frequency for the Chassis Ear.

INSPECTION continued...

Double Wishbone Suspension - Type A



Type A - Spring acting on Lower Wishbone

Commonly used on modern vehicles when a higher degree of camber control is wanted. This system is frequently used with a Coil-over Shock Absorber system as shown in the diagram above.

Lower Ball Joint

The Lower Ball Joint operates in extension (pin is pulled away from the housing), so placing the Jack under the Lower Control Arm forces the Ball Joint Pin downwards. By placing a lever between the ground and the Tyre the Wheel can be lifted to reveal any wear in the Ball Joint.

INSPECTION continued...

Upper Ball Joint

With the Jack under the Lower Control Arm the angle of the Upper Arm is as close as possible to the normal ride height angle. The Upper Ball Joint is mainly subjected to lateral loads so pushing the top of the Tyre in and out is usually enough to highlight Ball Joint Wear. Many OE stabilising Ball Joint (non-load carrying) are spring loaded, so squeezing the Pin into the housing with a large pair of grips can be a useful test. Regardless of the joint type there should be no freeplay.

Upper Spring Mount

In addition to a visual inspection, raise the vehicle with the suspension hanging, grab both sides of the highest spring coil you can safely reach (without squashing hand between spring and tower). shake coil up and down vigorously, there should be no freeplay, movement or noise.

Lower Shock Absorber/Spring Bushing

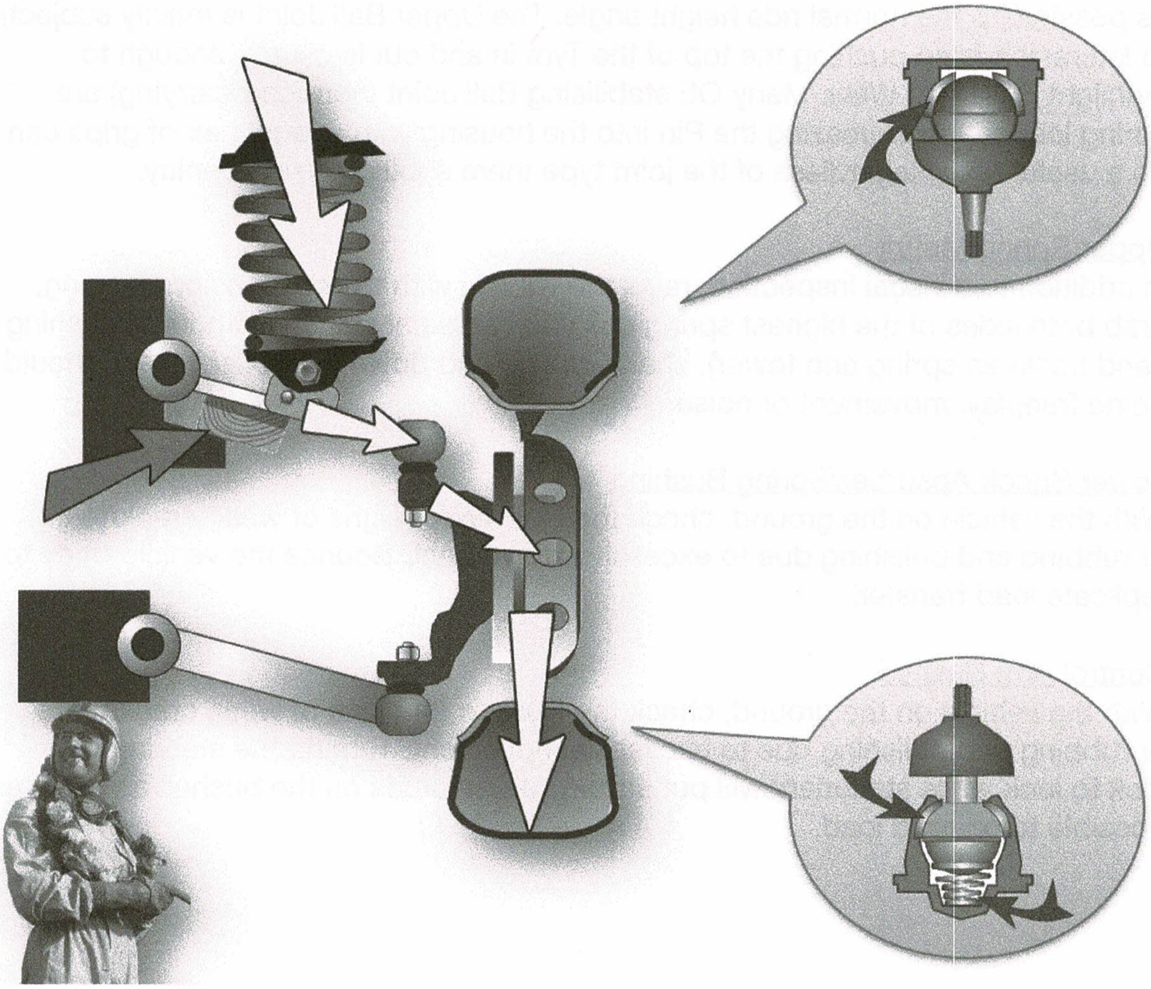
With the vehicle on the ground, check the Bushes for signs of wear, crack/tears or rubbing and polishing due to excessive movement. Bounce the vehicle body to replicate load transfer.

Control Arm Bushes

With the vehicle on the ground, check the Bushes for signs of wear, crack/tears or rubbing and polishing due to excessive movement. Turning the steering from lock to lock while stationary will put strong lateral forces on the bushes as close as possible to on road load.

INSPECTION continued...

Double Wishbone Suspension - Type B



Type B - Spring acting on Upper Wishbone

Not as common as Type A due to the increased encroachment into the Engine Bay by the upper wishbone mounting making this design less practical for transverse engine configurations. But still providing a higher degree of camber control than MacPherson Strut.

Lower Ball Joint

With the block under the Upper Control Arm the angle of the Lower Control Arm is as close as possible to the normal ride height angle. The Lower Ball Joint is mainly subjected to lateral loads so pushing the bottom of the Tyre in and out is usually enough to highlight Ball Joint wear. Many OE stabilising Ball Joints (non-load carrying) are spring loaded, so squeezing the Pin into the housing with a large pair of multi-grips can be a useful test. Regardless of the joint type there should be no freeplay.

INSPECTION continued...

Upper Ball Joint
The Upper Ball Joint operates in compression (pin is pushed into the housing). This system requires a special technique in order to accurately check the suspension. Place a block between the Frame and the Upper Control Arm before the vehicle is lifted, hardwood is preferred as it is strong enough to support the load, but is able to distort a little to prevent damage to the Frame and/or Upper Control Arm. Raise the vehicle under the Frame/Chassis/Cross Member, this allows the suspension to hang at an angle closer to the normal ride height.

The Upper Ball Joint can then be checked by placing a lever between the ground and the Tyre, the Wheel can be lifted to reveal any wear in the Ball Joint. Alternatively, the joint can be compressed by squeezing it with large multi-grips.

Upper Spring Mount
In addition to a visual inspection, raise the vehicle with the suspension hanging (block removed), grab both sides of the highest spring coil you can safely reach (without squashing hand between spring and tower). shake coil up and down vigorously, there should be no freeplay, movement or noise.

Lower Shock Absorber/Spring Bushing
With the vehicle on the ground, check the Bushes for signs of wear, crack/tears or rubbing and polishing due to excessive movement. Bounce the vehicle body to replicate load transfer.

Control Arm Bushes
The Lower Control Arm can be either a Wishbone type with front and rear bushes or a single bush arm with a Radius Arm. To check: start with the vehicle on the ground, check the Bushes for signs of wear, crack/tears or rubbing and polishing due to excessive movement. Turning the steering from lock to lock while stationary will put strong lateral forces on the bushes as close as possible to on road load.

Radius Arm Bushes
Where used the Radius Arm is used to prevent the wheel moving laterally. Radius Arm Bushes can be difficult prove out as the cause of a noise, this is because the forces that are applied on the road are very difficult to recreate in the workshop. A visual inspection is very important, outside of obvious cracks in the bushings, look for scuff marks that indicate excessive movement. Chassis Ears should pinpoint the cause, also a digital action camera (such as a GoPro) can be helpful if the noise is of to lower frequency for the Chassis Ear.

DIAGNOSIS

Chassis Ear

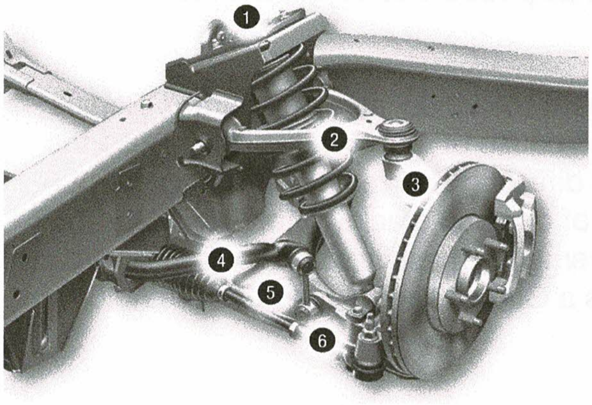
Chassis Ear's consist of one or more Contact Microphone's that are connected either by wires or wirelessly to a main receiver unit. The Contact Microphone consists of a clamp, receiver and amplifier. The vibrations associated with a noise are sent as a electronic waveform to the Main Receiver Unit where they are output either as sound, a visible scale (LED lights or digital graph), or both.

STEELMAN
STEELMAN
1
2
3
4

The operation of a Contact Microphone is very precise. Unlike the sound which can carry noise over a great distance, the vibration associated with the noise will be absorbed or severely dampened by flexible joints. This is how the Chassis Ear accurately identifies the source of the noise.

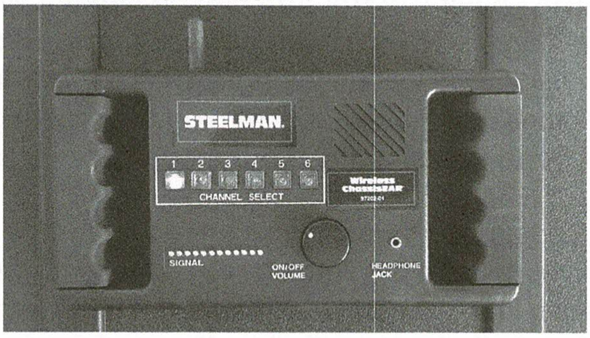
Procedure:

1. Road test the vehicle with the driver
2. Estimate location of noise
3. Connect the Microphone Clamps to a variety of components in that location. *See example:*



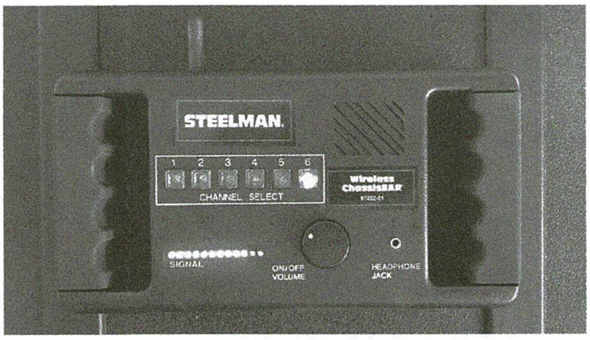
1. Upper Spring Mount
2. Upper Wishbone
3. Steering Knuckle
4. Sway Bar
5. Lower Control Arm
6. Tie Rod End

4. Select Channel #1

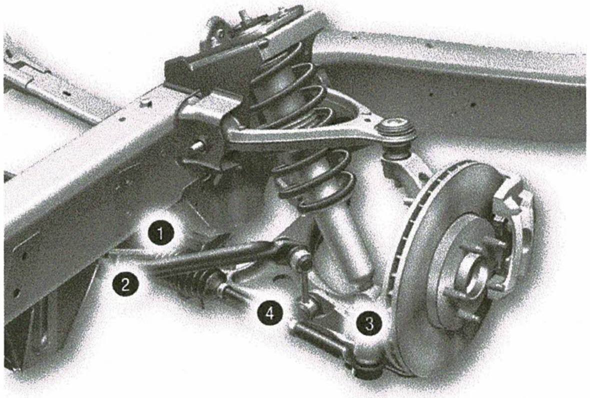


5. Road test the vehicle under the conditions required to produce the noise
6. Repeat step 5 for each Channel, in this example the knock was only detected on Channel #6

DIAGNOSIS continued...

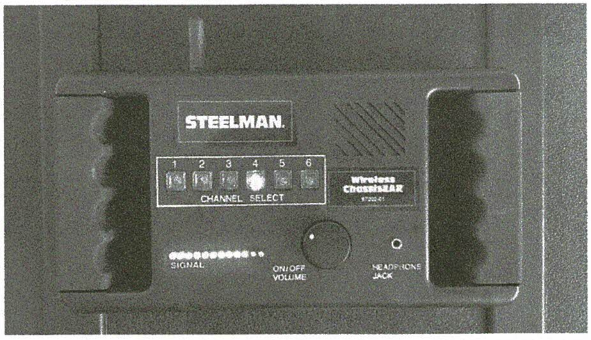

STEELMAN.
1 2 3 4 5 6
CHANNEL SELECT
Wireless ChassisEAR
SIGNAL
ON/OFF VOLUME
HEADPHONE JACK

7. Once the noise has been linked to one of the channels, relocate all of the sensors to that vicinity. *See example:*



1. Steering Rack Housing
2. Steering Rack Retaining Bracket
3. Tie Rod End Pin Crown Nut
4. Tie Rod

8. Repeat steps 4 to 6, *in this example the knock was only detected on Channel #4*


STEELMAN.
1 2 3 4 5 6
CHANNEL SELECT
Wireless ChassisEAR
SIGNAL
ON/OFF VOLUME
HEADPHONE JACK

9. If necessary, continue repeating steps 7 and 8 until the exact component is identified. *In this example the knock was only evident on the Tie Rod, if the Knock was also evident on the Tie Rod End Pin Crown Nut this would suggest the Tie Rod End (as it takes two surfaces to make contact to create a knock). The cause of the knock is the Rack End Bush and it was not possible to fit a Microphone Clamp to the Rack Shaft*
10. Carry out repair as required.

Caution: *Remember that subframe mountings can also be the source of movement and/or noises!*

Digital Action Camera

The use of video recording has become a lot more affordable with the commercialisation of digital action camera's (such as a GoPro). These cameras are affordable, shock proof, water proof and a large variety of mountings are available to make attaching them easy. This technique is particularly useful for identify bushes that have excessive movement but do not produce noise (4WD Radius Arm Bushes are one particular example). Unfortunately the movement found on numerous videos is not adequately represented by screen shots, so it cannot be shown in this manual.

Tips:

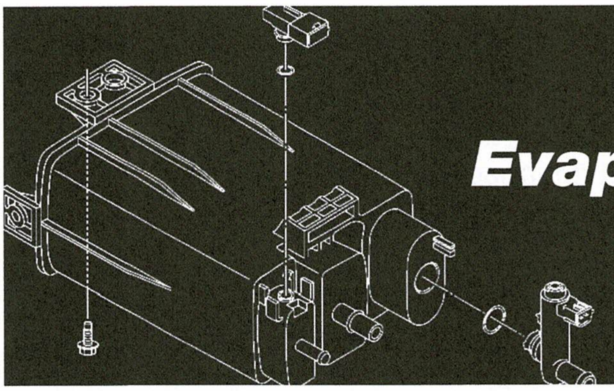
- Mount the camera as solidly as possible to the vehicle chassis
- Use multiple cable ties as extra safety leashes incase the camera dislodges from the mounting

MASKING

"Yeah, you fixed the noise but you've created another noise":

- Have you ever been confronted by this response?
- If so, you are not alone
- It is a well known phenomenon called "Masking"where a higher frequency masks a lower frequency noise
- Very difficult to avoid this issue, your primary role is to correct the noise that the customer has complained about
- Best practice is to perform a thorough road test and try to identify the secondary noise before returning the vehicle to the customer!

NOTES



Section iv

Evaporative Emission Systems

CONTENTS

INTRODUCTION 64
EURO Evaporative Emissions (inc. AU & NZ): 64
US Enhanced EVAP Systems - LDP Type: 64
US Enhanced EVAP Systems - FTPS Type: 65
US Refuelling Vapour Recovery (RVR) Systems: 66
US vehicles in Australia and New Zealand: 67

VEHICLES 67

TESTING 68
Check DTC's 68
Check the Canister Vent Valve 69
Check the Purge Control Valve 70
Check the Fuel Tank Pressure Sensor 71
Check EVAP System integrity with a Smoke Machine 72

INTRODUCTION

EURO Evaporative Emissions (inc. AU & NZ):

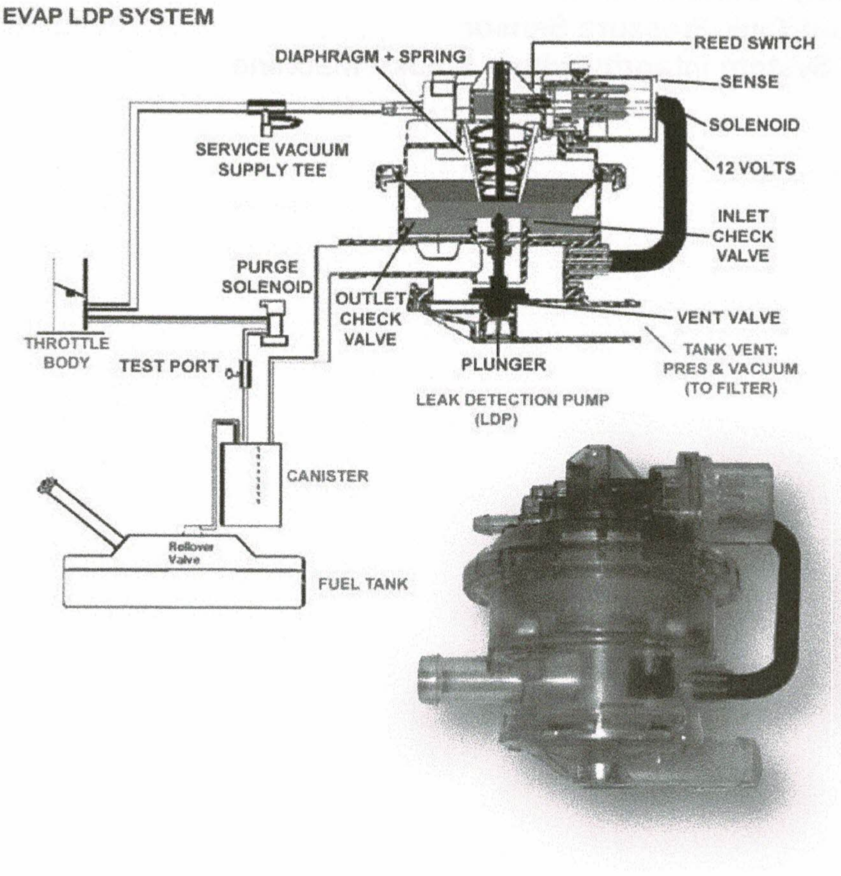
- All non-exhaust emissions
- Fuel vapours are called Volatile Organic Compounds (VOC's)
- 23% of VOC's in petrol vehicles are evaporative
- The EVAP standard and test has not changed since EURO III or ADR79/01 implemented in 2005-2006
- Limit is 2g/day
- EOBD does not require an EVAP monitor, it only requires the Purge Valve Solenoid to be covered by the Continuous Component Monitor
- A Swedish study found the 30% of EU vehicles failed the VT SHED test if running on E5 (5% Ethanol)

Note: *VT SHED – Variable Temperature Sealed House for Evaporative Determination!*

US Enhanced EVAP Systems - LDP Type:

Enhanced Evaporative Emission systems developed for the US are primarily to address unleaded containing ethanol:

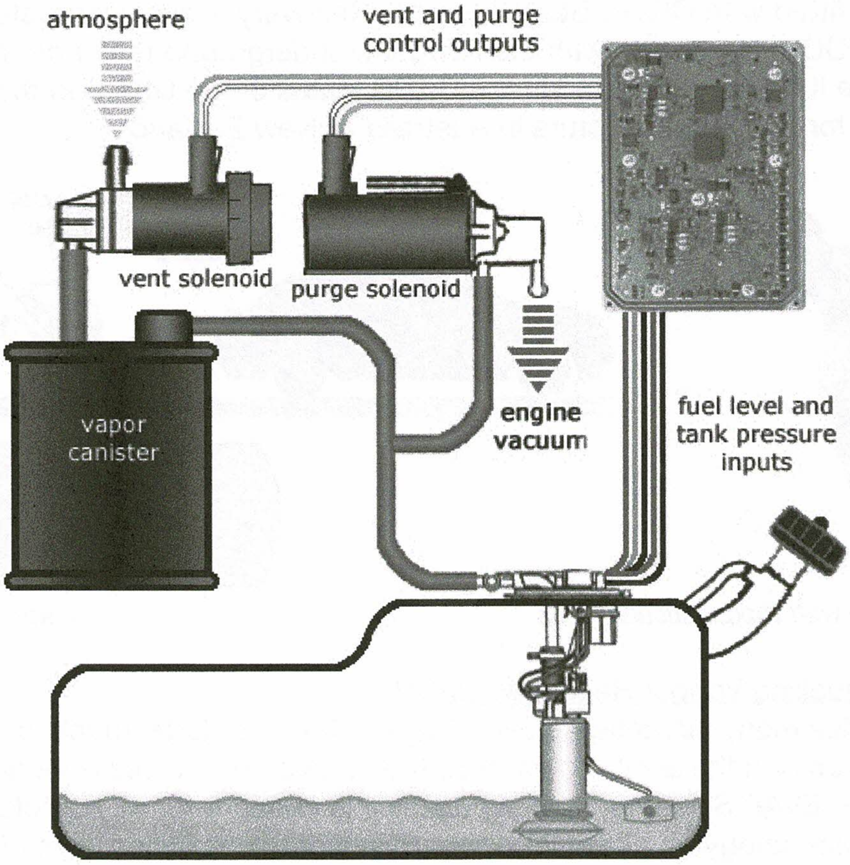
- Ethanol evaporates at a lower temp. and is harder to purge
- Requires larger canister
- Requires a different activated carbon composition
- US systems reached their height of complexity in the late 1990's with complex valve arrangements and a Leak Detection Pump (LDP)


EVAP LDP SYSTEM
DIAPHRAGM + SPRING
REED SWITCH
SENSE
SOLENOID
12 VOLTS
INLET CHECK VALVE
SERVICE VACUUM SUPPLY TEE
PURGE SOLENOID
OUTLET CHECK VALVE
VENT VALVE
TANK VENT: PRES & VACUUM (TO FILTER)
THROTTLE BODY
TEST PORT
PLUNGER
LEAK DETECTION PUMP (LDP)
CANISTER
Rollover Valve
FUEL TANK

INTRODUCTION continued...

US Enhanced EVAP Systems - FTPS Type:
Today, the US systems are meeting higher emission standards with physically simpler EVAP systems:

- Most systems use a Fuel Tank Pressure Sensor (FTPS) with one Vent Valve and one Purge Valve
- Instead relying on sophisticated solenoid control meaning that EVAP LDP's were no longer required
- Current US limit is 0.32 g/day (EPA) and 0.17 g/day (CARB)
- Future Californian limit, ZERO EVAP phase in from 2017 to 2022


atmosphere
vent and purge control outputs
vent solenoid
purge solenoid
vapor canister
engine vacuum
fuel level and tank pressure inputs

So, why cover the US systems.

Because the old systems were costly and complex many manufacturers would produce different vehicles for the US and US manufacturers would leave the system off of export vehicles.

Now that they have been simplified it is cheaper for US manufacturers to send the complete system to export markets such as Australia. They turn off the EVAP Monitor which means that the EVAP System is not tested for its functionality. This meets ADR79/01 onwards. Instead the electronic components of the EVAP System are monitored by the Comprehensive Component Monitor, which will only detect the integrity of the sensor, solenoids and their electrical circuits.

INTRODUCTION continued...

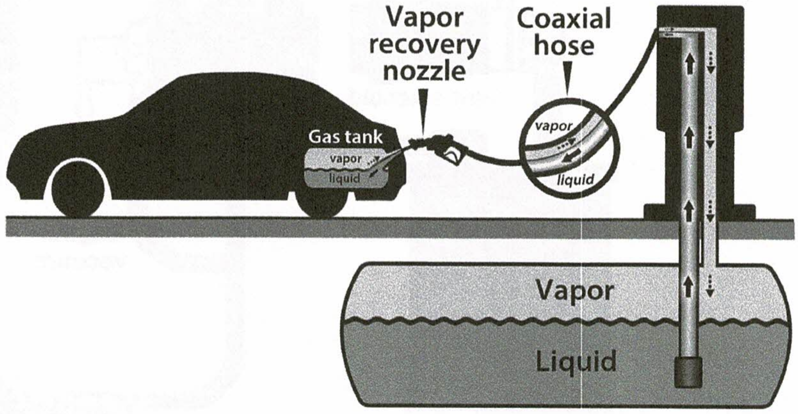
US Refuelling Vapour Recovery (RVR) Systems:
In addition to the EVAP System, RVR is another US requirement.
There are two types of RVR systems:

- Stage II Vapour Recovery
- Onboard Refuelling Vapour Recovery (ORVR)

Stage II Vapour Recovery

Stage II Vapour Recovery is infrastructure based with vapour being recovered at the fuelling station. This system is costly and requires third party processing of the stored vapours but has the one advantage that it is effective on older vehicles not fitted with ORVR. Stage I Vapour Recovery is a similar system used to trap the VOC's associated with the filling the underground tank from fuel tanker trucks. Stage II is only mandated in the CARB states of the USA and there is no requirement for such infrastructure in Australia or New Zealand.

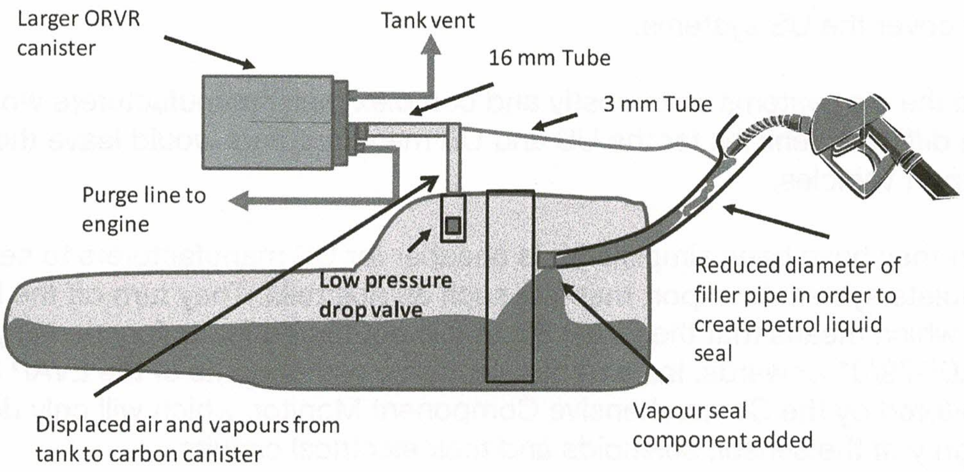
Stage II Nozzle with vapour suction holes


Vapor recovery nozzle
Coaxial hose
Gas tank
vapor
liquid
vapor
liquid
Vapor
Liquid

Stage II Infrastructure

Onboard Refuelling Vapour Recovery (ORVR)

ORVR provides many advantages over Stage II, these include: much lower cost of implementation and the ability to process the recovered vapours onboard. As with the Enhanced EVAP Systems, in many cases it is cheaper for manufacturers to include the technology on all vehicles regardless of the emission laws of the region in which they are being delivered.

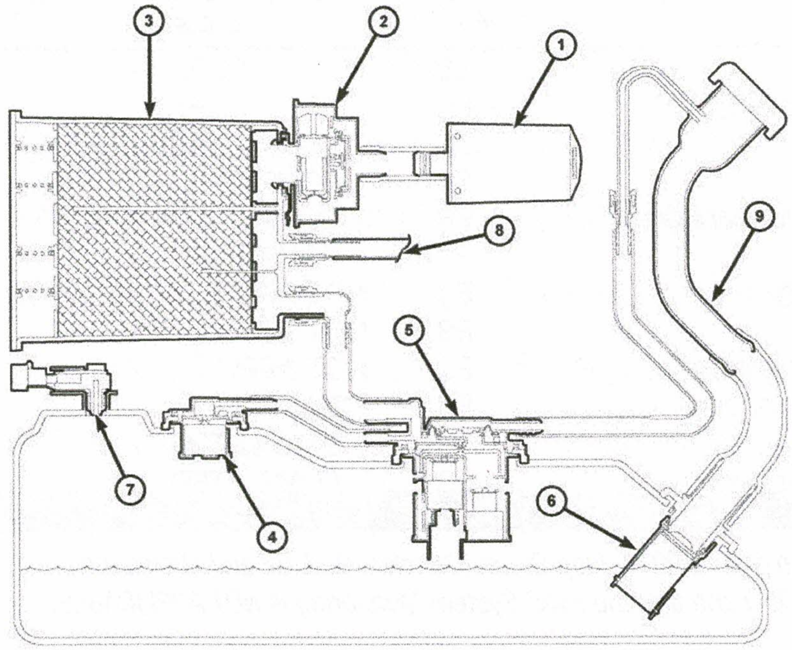

Larger ORVR canister
Tank vent
16 mm Tube
3 mm Tube
Purge line to engine
Low pressure drop valve
Reduced diameter of filler pipe in order to create petrol liquid seal
Displaced air and vapours from tank to carbon canister
Vapour seal component added

VEHICLES

US vehicles in Australia and New Zealand:

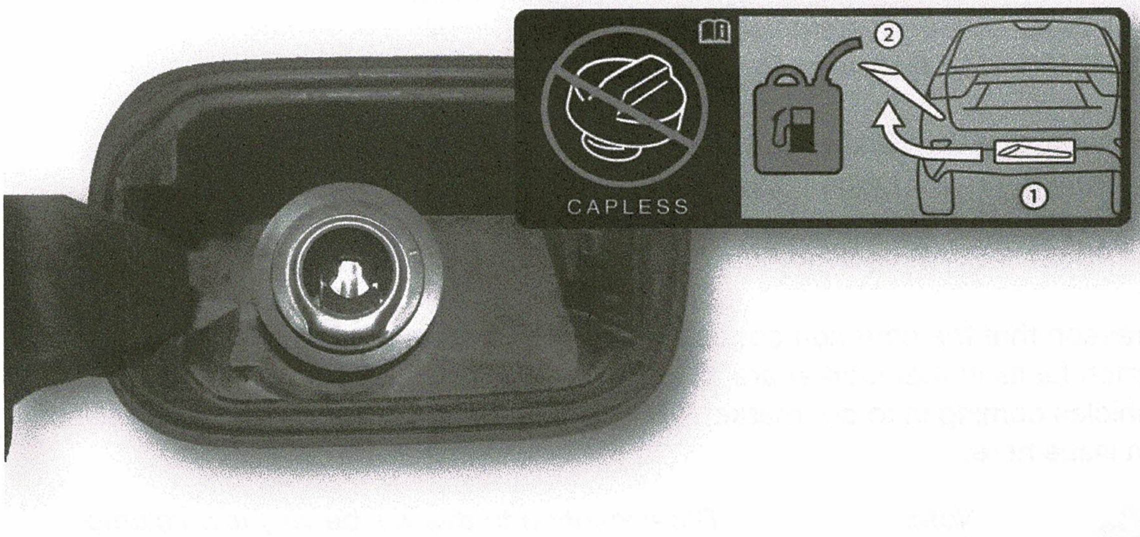
2015 Jeep Grand Cherokee 3.6L V6

Since 2012 the Jeep Grand Cherokee models fitted with petrol engines have been coming into Australia and New Zealand with both FTPS EVAP and ORVR.



1. Air Filter
2. Vent Valve
3. Canister
4. Vent Valve
5. Control Valve
6. ORVR Valve
7. Pressure Sensor
8. to Purge Solenoid
9. Filler

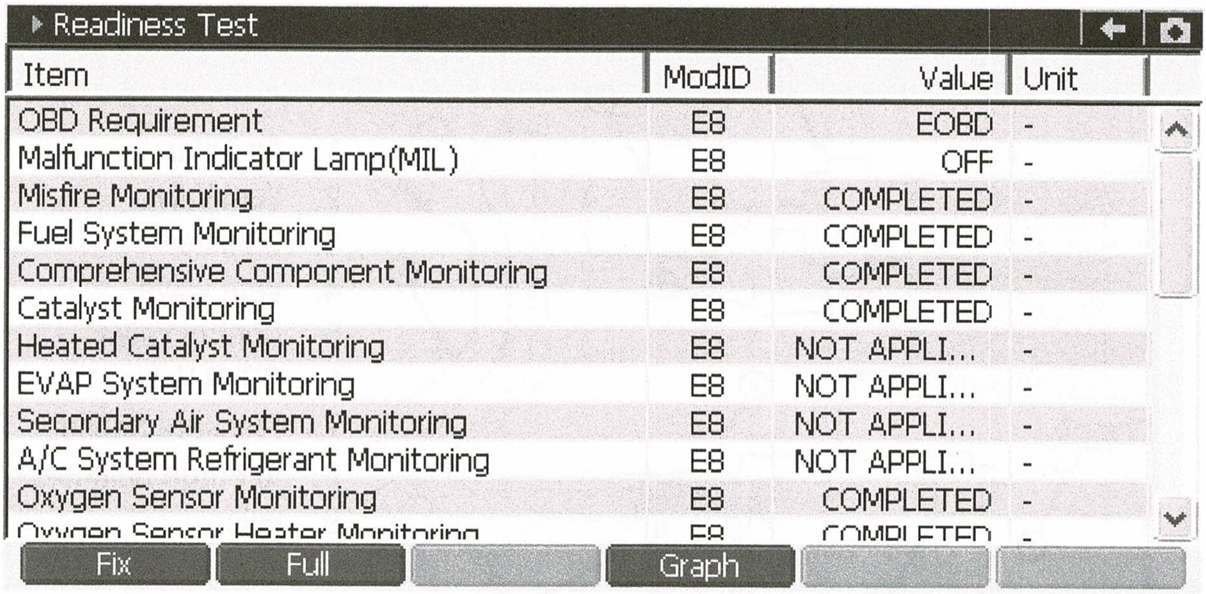
These vehicles are also fitted with a “Capless” Fuel Filler. This incorporates the narrow neck required to create the liquid seal as well as an automatically sealing door that closes when the nozzle is removed. A sealed fuel filler is a key requirement of the EVAP System and many faults on vehicles in the US have been attributed to loose or faulty Fuel Filler Caps.



An emergency filling funnel is provided in the tool kit. Purchasing a suitable funnel for the workshop is recommended.

TESTING

Most OE procedures guide the technician through a diagnostic procedure starting with the EVAP Monitor. These monitors are deactivated for all EOBD markets. An alternative procedure needs to be adopted.



Item	ModID	Value	Unit
OBD Requirement	E8	EOBD	-
Malfunction Indicator Lamp(MIL)	E8	OFF	-
Misfire Monitoring	E8	COMPLETED	-
Fuel System Monitoring	E8	COMPLETED	-
Comprehensive Component Monitoring	E8	COMPLETED	-
Catalyst Monitoring	E8	COMPLETED	-
Heated Catalyst Monitoring	E8	NOT APPLI...	-
EVAP System Monitoring	E8	NOT APPLI...	-
Secondary Air System Monitoring	E8	NOT APPLI...	-
A/C System Refrigerant Monitoring	E8	NOT APPLI...	-
Oxygen Sensor Monitoring	E8	COMPLETED	-
Oxygen Sensor Heater Monitoring	E8	COMPLETED	-

This image was taken from a 2015 Jeep Grand Cherokee 3.6L V6 and shows the OBD Requirement as EOBD and that the EVAP System Monitoring is NOT APPLICABLE.

Check DTC's
This is always the first logical test because unless you have EVAP DTC's logged it's unlikely that you'll be testing the system!

Most common EVAP Codes in AU & NZ:
- P0440 – EVAP System Malfunction
- P0443 – EVAP System Purge Control Valve Circuit
- P0446 – EVAP System Vent Control Valve Circuit
- P0450 – EVAP System Pressure Sensor Malfunction

Most common EVAP Codes in the US:
- P0455 – EVAP Large Leak Detected
- P0456 – EVAP Small Leak Detected
- P0457 – EVAP Leaking Fuel Cap Detected

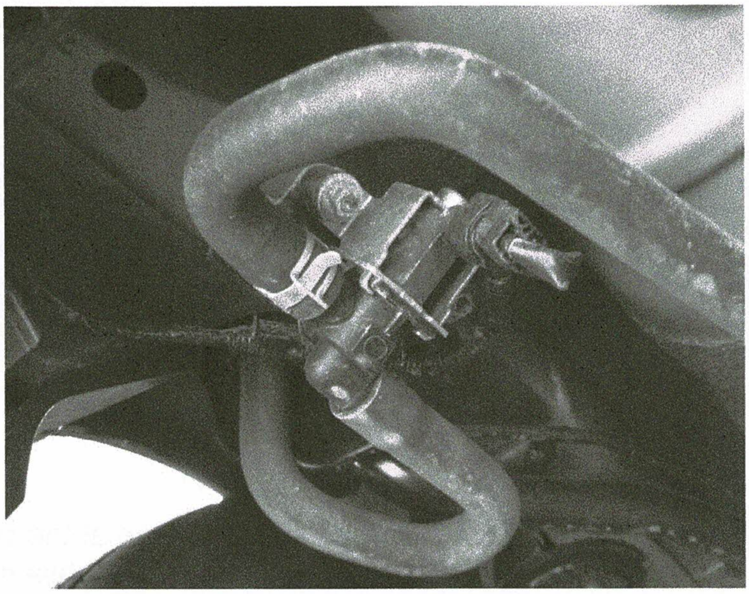
The reason that the common codes vary so greatly from the US is that the most common faults in that market are all logged by the monitor test. As the vast majority of vehicles coming in to our market will have the monitors turned off these will not be an issue here.

Note: *The exception to this will be very low volume vehicles where it is not financially viable to reprogram and grey imports of which the Ford F-Truck makes up a majority!*

TESTING continued...

Check the Canister Vent Valve

The Canister Vent Valve is usually located on or adjacent to the Charcoal Canister, in older vehicles that Charcoal Canister was often located in the Engine Bay. Modern vehicles are more likely to located the Charcoal Canister alongside the Fuel Tank, underneath the vehicle.



Actuate the Valve:

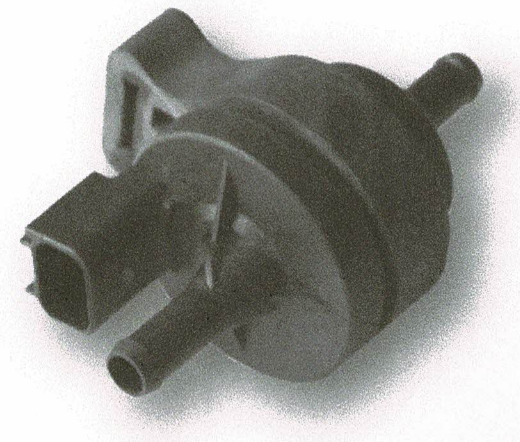
1. KOEO – Check PCM Command by measuring voltage at the solenoid
   Use Scan Tool actuation feature to command opening, while measuring the voltage by back-probing the connector. See table below:

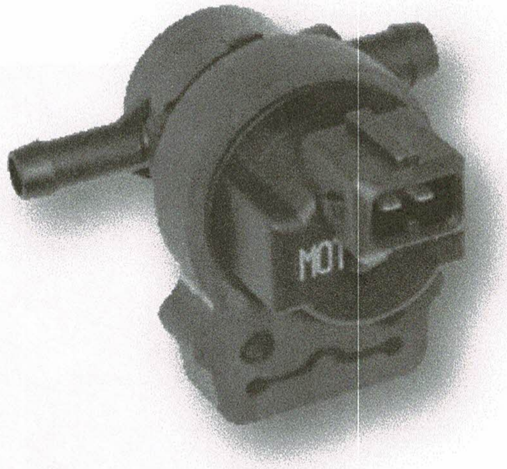
Command (Duty Cycle)	Voltage
0%	0 Volts
10%	1.2-1.4 Volts
20%	2.4-2.8 Volts
30%	3.6-4.2 Volts
40%	4.8-5.4 Volts
50%	6.0-7.0 Volts
60%	7.2-8.4 Volts
70%	8.4-9.8 Volts
80%	9.6-10.8 Volts
90%	10.8-12.6 Volts
100%	12.0-14.0 Volts

2. Jump the solenoid with a 12 Volt Battery across the two terminals, air should pass through valve freely
3. Disconnect Valve – passage should be sealed both ways

TESTING continued...

Check the Purge Control Valve
The Purge Control Valve is usually located in the Engine Bay, the closer the valve is located to the engine the more accurately it can control the vapour return.





Actuate the Valve:

1. KOEO – Check PCM Command by measuring voltage at the solenoid
   Use Scan Tool actuation feature to command opening, while measuring the voltage by back-probing the connector. See table below:

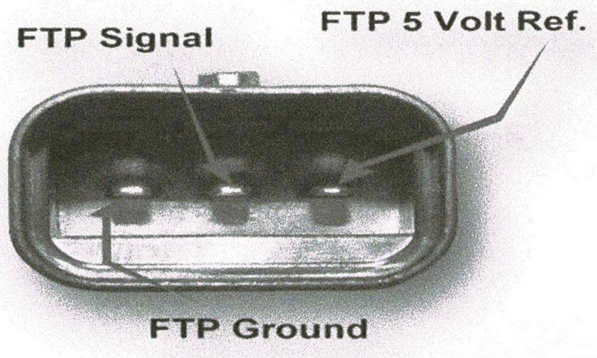
Command (Duty Cycle)	Voltage
0%	0 Volts
10%	1.2-1.4 Volts
20%	2.4-2.8 Volts
30%	3.6-4.2 Volts
40%	4.8-5.4 Volts
50%	6.0-7.0 Volts
60%	7.2-8.4 Volts
70%	8.4-9.8 Volts
80%	9.6-10.8 Volts
90%	10.8-12.6 Volts
100%	12.0-14.0 Volts

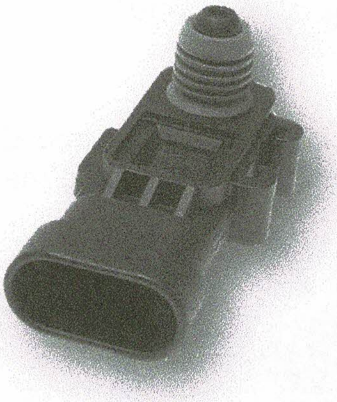
2. Jump the solenoid with a 12 Volt Battery across the two terminals, air should pass through valve freely
3. Disconnect Valve – passage should be sealed both ways

TESTING continued...

Check the Fuel Tank Pressure Sensor

The Fuel Tank Pressure Sensor (FTPS) is used to monitor the pressure within the Fuel Tank. The PCM uses this information to prevent damage occurring to the tank either from excessive pressure or vacuum. It also uses it to calculate the desired Purge Control Valve duty cycle.





Check the Live Data with a Compatible Scan Tool:

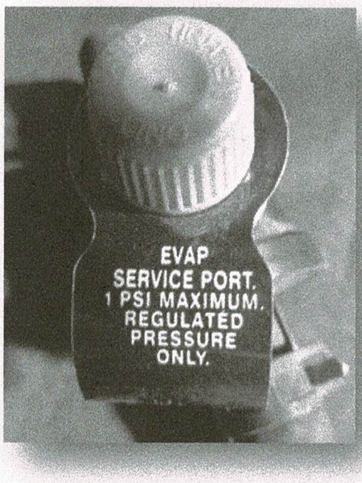
1. Should be between 0.10 to 4.90 Volts
   > 5 Volts = open in ground circuit
   > 0 Volts = open in reference circuit
2. If reading 0 or 5 Volts unplug sensor during KOEO
   > If voltage moves within range sensor is faulty
   > If voltage remains outside of parameter wiring is faulty

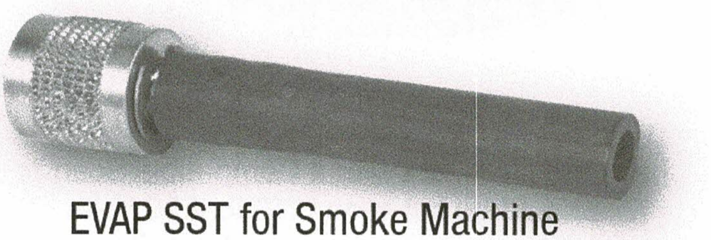
TESTING continued...

Check EVAP System integrity with a Smoke Machine
In the AU and NZ markets there are very few vehicles that will run the EVAP Monitor and therefore the integrity of the EVAP System is not tested. However, for those vehicles that do, there will likely be a need from time to time to test the EVAP System for leaks.

Note: *In the US it is estimated that 3 in 4 Evaporative Emission System faults are due to system leaks!*

All vehicles with an Enhanced EVAP System should have and EVAP Service Port between the Canister and the Purge Valve.




EVAP SST for Smoke Machine

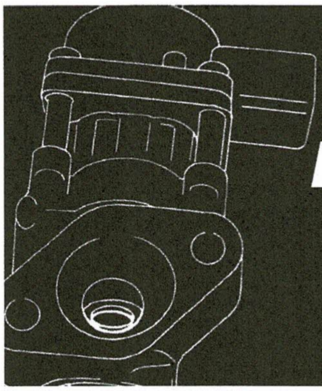
Many vehicles such as the Jeep have the service port integrated into the Purge Valve located in the Engine Bay.

Procedure:

1. Warm up the Smoke Machine and bleed/prime the hose
2. Attached a smoke machine to the EVAP Service Port with the special service connector
3. Adjust the output pressure to a maximum of 7kPa
4. Remove the Fuel Filler Cap to allow smoke to fill the system
5. Once smoke reaches the filler, refit the cap
6. Remove the Air Intake Tube and wedge the throttle open
7. Inspect the system for leaks

Tips:

- If smoke escapes from the Air Filter attached to the Charcoal Canister check the Canister Vent Valve and Safety Valve pressure release and replace valve if required.
- If smoke escapes from the throttle body, check the Purge Control Valve
- If smoke escapes from the fuel filler, check the cap as well as the filler neck for damage.



Section v

Exhaust Gas Recirculation (EGR) Diagnosis

CONTENTS

INTRODUCTION 74

Petrol Engines 74

Diesel Engines 75

DESIGN AND OPERATION 75

Monitoring and Logic 76

Checking the Intake Air to EGR Ratio at Idle 77

DIAGNOSIS 79

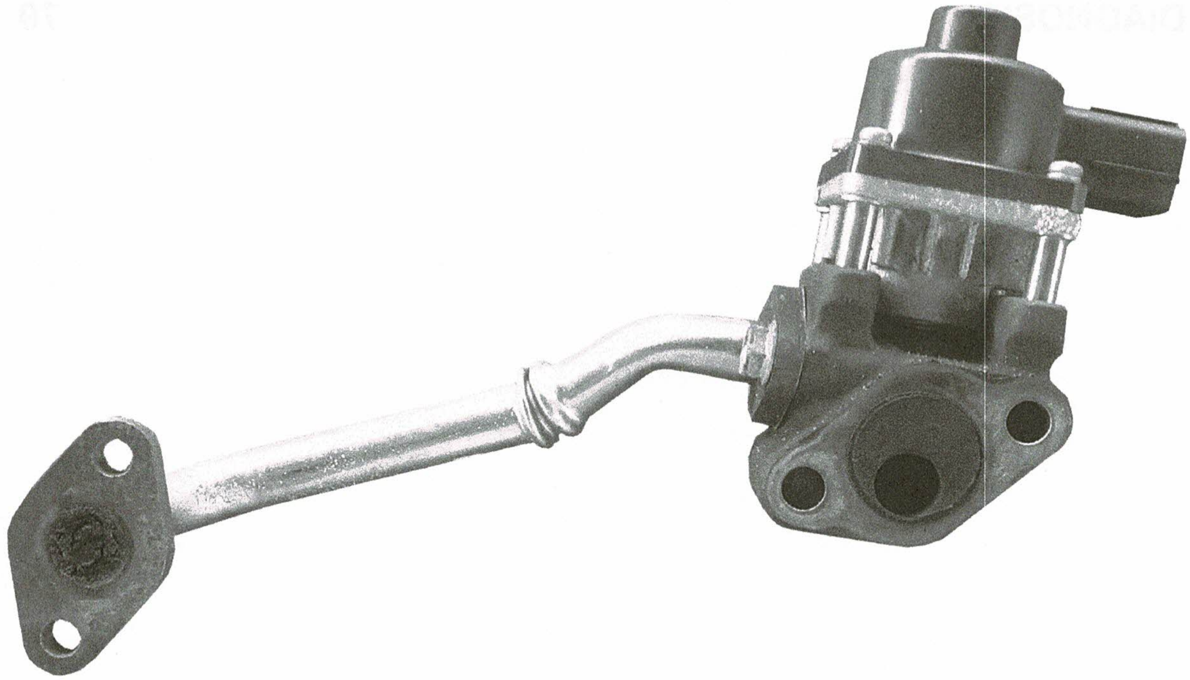
INTRODUCTION

Exhaust Gas Recirculation (EGR) has played a pivotal role in emission reduction since the earliest Australian Design Rules (ADR) in the 1970's. Since that time the design of the EGR Valve and its associated components have evolved, but the principle of operation remains the same.

Even though EGR has been on our vehicles for over 40 years its operation is still misunderstood, especially with its use on electronically controlled engines! Many technicians think that blocking off the system will go unnoticed by the PCM. Not only is this illegal it can often lead to more issues. Blocking the EGR of a diesel vehicle will not improve performance (the abundance of air in a Compression Ignition Engine is not compromised by EGR during light to medium throttle) and for both petrol and diesel vehicles the PCM programming shuts down all EGR during high load and full throttle operation.

Petrol Engines

EGR Systems on petrol engines are less troublesome that their diesel version. This is largely due to the lower presence of oil mist that has been directed into the Intake Manifold by the Positive Crankcase Ventilation (PCV) System. Contamination issues do increase as the engine wears.



Blocked EGR Pipe from a 2008 Suzuki Swift with 220,000km on the odometer, notice that the Valve end is completely clear but once the gases come into contact with the oil mist they solidify and build up.

The vast majority of fault diagnosis on the EGR System for petrol engines is related to EGR Valve failures. These faults reside in the electronic control, vacuum actuator and/or mechanical failures of the valve.

DESIGN AND OPERATION

Diesel Engines

EGR Systems on diesel vehicles have proven to be more troublesome. EGR & Intake System contamination is arguably the largest issue affecting CRD engines, not only in Australia and New Zealand, but globally. Most manufacturers are affected to varying degrees and for the most part these manufacturers are blaming poor quality fuels in Australia for their concerns. This is clearly not the case as a quick search of automotive forums around the world will show that these same contamination issues are rife in North America, South America, Africa, Japan, United Kingdom and Europe to name but a few! In fact, since the standardisation of Ultra Low Sulphur Diesel (ULSD) Australia's diesel is amongst the highest quality in the world!

The true cause of these issues is a combination of the following factors:

- Aggressive EGR combined with oil mist from Closed Crankcase Ventilation (CCV)
- Design flaws
- Environment & driving method
- Poor servicing

These points are in no particular order and most vehicles can operate without adverse effect if only one of the above is impacting on the engine operation. But when vehicles are operating under the duress of a multitude of these points the result is excessive contamination on a widely varying scale.

These issues are now on the decline with the latest generation diesel vehicles using a combination of:

- Improved Oil Separators (usually integrated into the Valve Cover or located on the side of the Cylinder Block)
- Adoption of Low Pressure EGR Systems

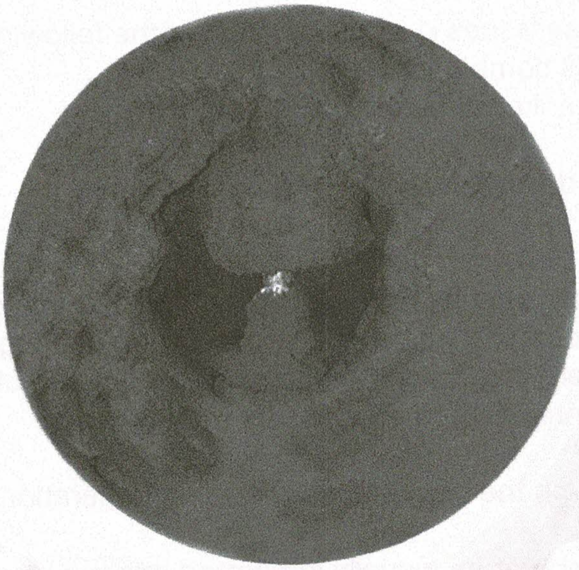
Unlike High Pressure EGR that recirculates the exhaust gases before they enter the Turbo Charger and deposits them in the high pressure intake manifold (after the Turbocharger), Low Pressure EGR recirculates the exhaust gases after the Turbo Charger and more importantly the Diesel Particulate Filter (DPF) where the particulates are trapped and removed from the EGR stream. The EGR gases then enter the air intake, upstream (low pressure/suction side) of the Turbo Charger turbine.

The use of Low Pressure EGR does not suit the varying operating conditions of an on-road vehicle alone and therefore is only suitable for use in conjunction with High Pressure EGR. Because the Low Pressure EGR deposits the recycled gas upstream for the Turbo Charger turbine a filter is added to ensure that particles and contaminants do not damage the Turbo Charger or the Engine.

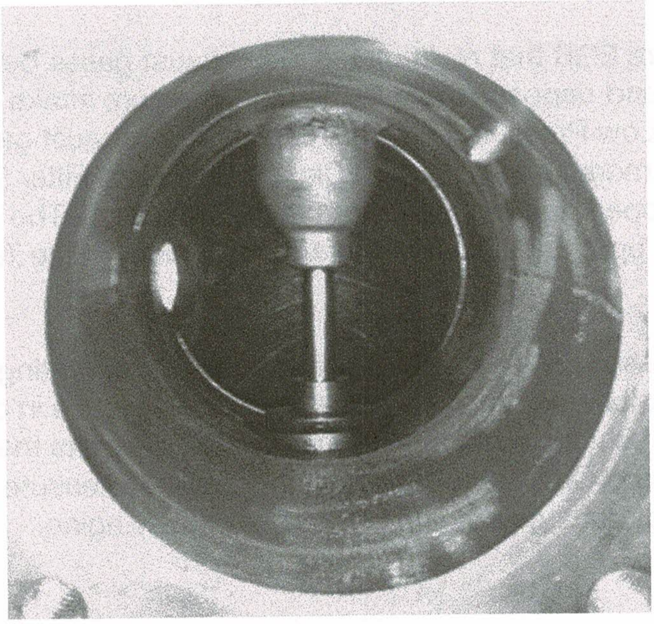
DESIGN AND OPERATION continued...

Monitoring and Logic

While some vehicles utilise an EGR Valve Position Sensor this does not prove to the PCM that the exhaust gasses are flowing. In order to correctly adjust the fuel trim the PCM must know the amount of exhaust gas that is recirculating, this is achieved by monitoring the intake air quantity immediately before and after the opening of the EGR. The PCM uses this value to calculate the air to EGR ratio, which in turn influences the fuel trim. If the PCM commands the EGR Valve open and the intake air quantity does not alter, the PCM will log a pending code. If the same fault occurs within the Two Drivecycle Detection Logic parameters and no EGR Component Fault DTC's are logged the PCM log P0401 – EGR Insufficient Flow and illuminate the Malfunction Indicator Lamp (MIL).



Heavily contaminated Air Intake of a Toyota 1KD engine, showing the restriction of the intake.



The same vehicle after cleaning

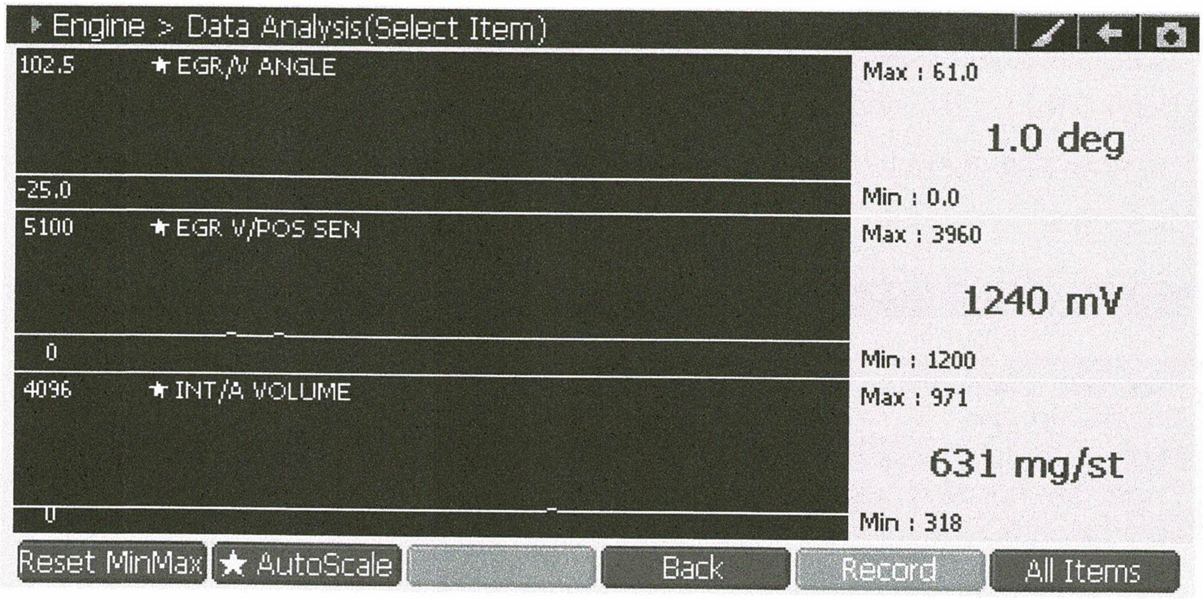
DESIGN AND OPERATION continued...

Checking the Intake Air to EGR Ratio at Idle

Diesel

On diesel engines it is possible to start the engine from cold and monitor the Live Data until the EGR Valve opens and then calculate the ratio:

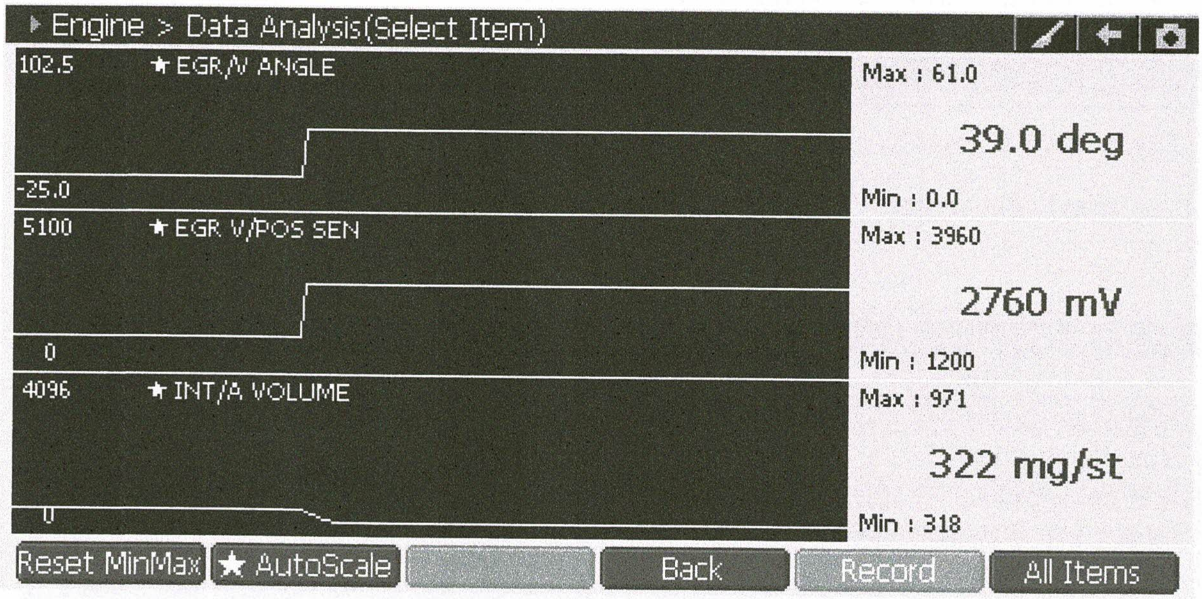
A - INT/A VOLUME with Valve OPEN (mg/st) = 322
B - INT/A VOLUME with Valve CLOSED (mg/st) = 631
A ÷ B × 100 = 51.03%
(The remaining 48.97% is exhaust gas)



Engine > Data Analysis(Select Item)

102.5 / -25.0	★ EGR/V ANGLE	Max : 61.0 1.0 deg Min : 0.0
5100 / 0	★ EGR V/POS SEN	Max : 3960 1240 mV Min : 1200
4096 / 0	★ INT/A VOLUME	Max : 971 631 mg/st Min : 318

From cold start the PCM provides minimal EGR, so all intake air is passing the MAF Meter



Engine > Data Analysis(Select Item)

102.5 / -25.0	★ EGR/V ANGLE	Max : 61.0 39.0 deg Min : 0.0
5100 / 0	★ EGR V/POS SEN	Max : 3960 2760 mV Min : 1200
4096 / 0	★ INT/A VOLUME	Max : 971 322 mg/st Min : 318

Once warm the PCM commands the EGR and the drop in intake air volume is indicative of EGR Flow

Because of the excess air present in the combustion chamber of diesel vehicles at idle, it is normal to see Intake Air to EGR ratios as high as 50%.

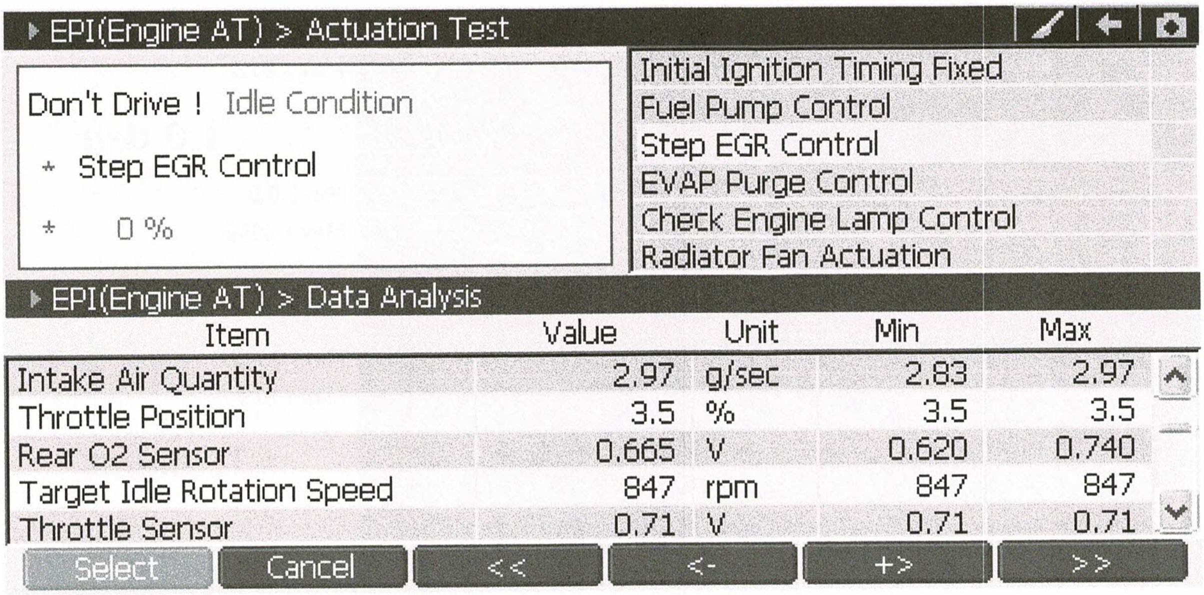
DESIGN AND OPERATION continued...

Checking the Intake Air to EGR Ratio at Idle

Petrol

On petrol vehicles EGR will not operate at idle unless commanded by a Scan Tool with actuation capabilities:

1. Engine idling at normal operating temperature
2. Connect Scan Tool and access actuation tests
3. Monitor the Intake Air Quantity


EPI(Engine AT) > Actuation Test
Initial Ignition Timing Fixed
Fuel Pump Control
Step EGR Control
EVAP Purge Control
Check Engine Lamp Control
Radiator Fan Actuation
EPI(Engine AT) > Data Analysis
Select
Cancel
<<
<-
+>
>>

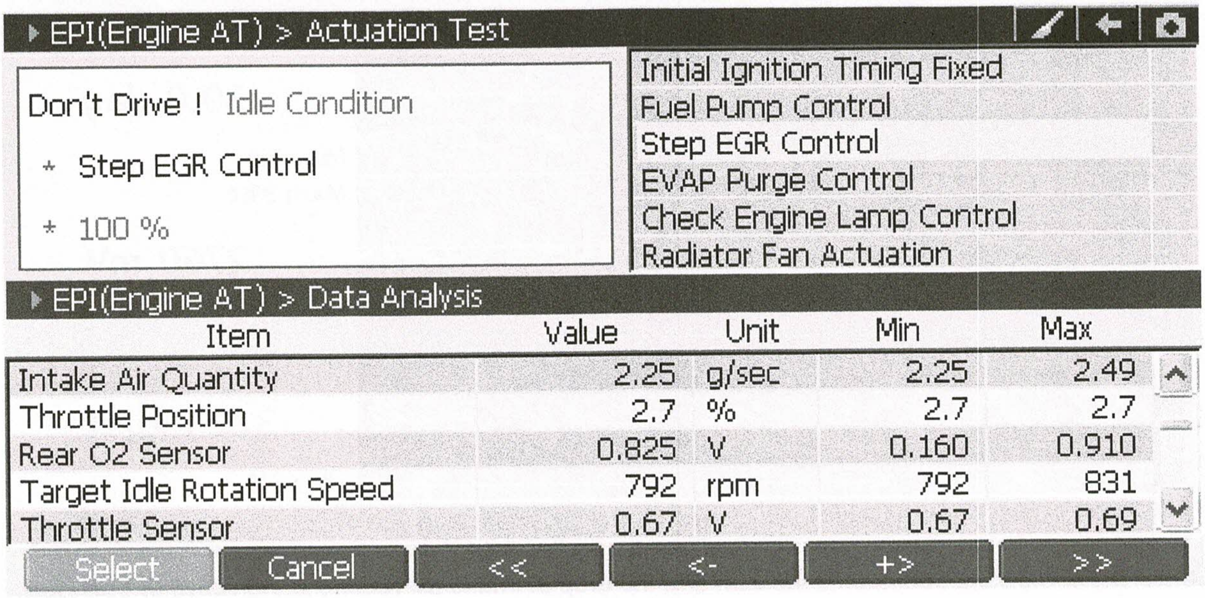
Don't Drive ! Idle Condition

* Step EGR Control

* 0 %

Item	Value	Unit	Min	Max
Intake Air Quantity	2.97	g/sec	2.83	2.97
Throttle Position	3.5	%	3.5	3.5
Rear O2 Sensor	0.665	V	0.620	0.740
Target Idle Rotation Speed	847	rpm	847	847
Throttle Sensor	0.71	V	0.71	0.71

4. Command the EGR Valve to 100% OPEN


EPI(Engine AT) > Actuation Test
Initial Ignition Timing Fixed
Fuel Pump Control
Step EGR Control
EVAP Purge Control
Check Engine Lamp Control
Radiator Fan Actuation
EPI(Engine AT) > Data Analysis
Select
Cancel
<<
<-
+>
>>

Don't Drive ! Idle Condition

* Step EGR Control

* 100 %

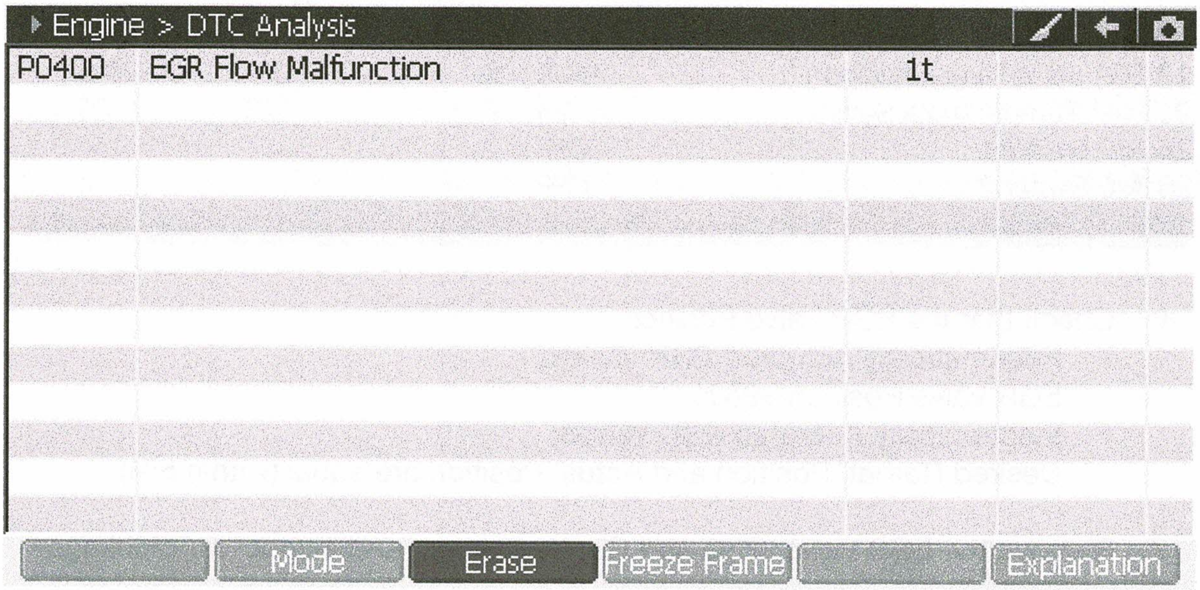
Item	Value	Unit	Min	Max
Intake Air Quantity	2.25	g/sec	2.25	2.49
Throttle Position	2.7	%	2.7	2.7
Rear O2 Sensor	0.825	V	0.160	0.910
Target Idle Rotation Speed	792	rpm	792	831
Throttle Sensor	0.67	V	0.67	0.69

5. Calculate the ratio: 2.25 ÷ 2.97 × 100 = 75.75%
   (the remaining 24.25% is exhaust gas)

DIAGNOSIS

1. Check DTC's
   If you have EGR Actuator or EGR Position Sensor fault codes test them as per manufacturers procedure before proceeding

2. If you have flow related codes carry out step 3:
   - P0400 – EGR Flow Malfunction (2 trip logic)
   - P0401 – EGR Insufficient Flow (2 trip logic)
   - P0402 – EGR Excessive Flow (2 trip logic)

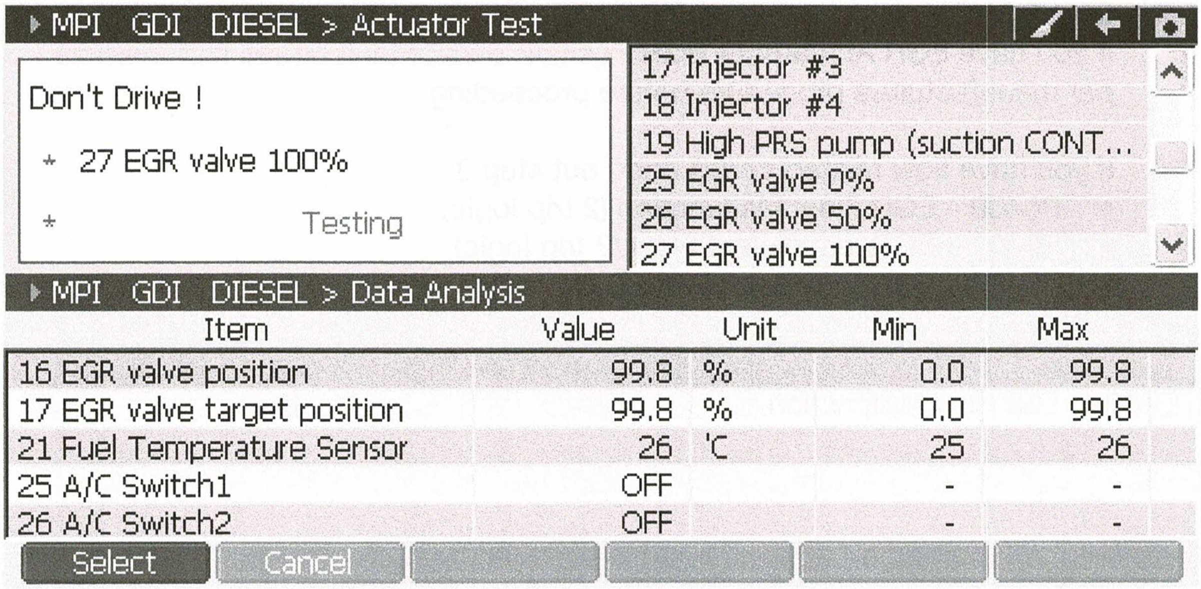


```
P0400   EGR Flow Malfunction                1t
```

3. Engine idling at normal operating temperature
4. Check Intake Air to EGR Ratio:
   - Diesel engines: see page 77
   - Petrol engines: see page 78

5. Actuate the Valve:
   - Pneumatically Actuated EGR Valves:
     Use a vacuum pump to actuate the valve and check that the actuator does not leak
   - Electronically Actuated EGR Valves:
     Actuate the EGR Valve using the Scan Tool function

DIAGNOSIS continued...


MPI GDI DIESEL > Actuator Test
MPI GDI DIESEL > Data Analysis
Select
Cancel

Don't Drive !

* 27 EGR valve 100%

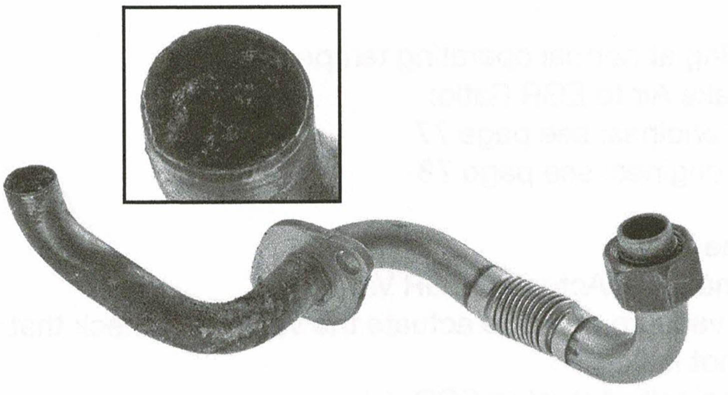
* Testing

17 Injector #3
18 Injector #4
19 High PRS pump (suction CONT...
25 EGR valve 0%
26 EGR valve 50%
27 EGR valve 100%

Item	Value	Unit	Min	Max
16 EGR valve position	99.8	%	0.0	99.8
17 EGR valve target position	99.8	%	0.0	99.8
21 Fuel Temperature Sensor	26	'C	25	26
25 A/C Switch1	OFF		-	-
26 A/C Switch2	OFF		-	-

6. Check that the EGR Valve Position
   - Pneumatically Actuated EGR Valves:
     EGR Valve Position >95%
   - Electronically Actuated EGR Valves:
     Desired (Target) Position and Actual Position are equal (within 5%)

7. Remove the EGR Valve, Pipe and Cooler (if fitted) and inspect for blockages



8. After cleaning, repairing or replacing the EGR Valve it may be necessary to carry out a relearn procedure before the component can function normally. This is usually carried out with a Scan Tool.

Note: *For Nissan the learning component is automatic. However you must clear the existing learned values from the PCM so that it can relearn itself.*

The relearn is to simply warm up the engine and then turn it off and confirm that you can hear the actuator closing within seconds of turning it off!

Section vi

Advanced Safety Systems

CONTENTS

INTRODUCTION	**82**
Advisory Systems	**82**
Intervention Systems	**82**
SENSORS	**83**
Echolocation Sensors	**84**
Vision Sensors	**85**
FEEDBACK	**88**
Visual	**88**
Audible	**88**
Haptic	**88**
FUTURE SYSTEMS	**89**
V2×	**89**
NOTES	**90**

INTRODUCTION

The array of Advanced Safety Systems have now been grouped together into what is universally known as Advanced Driver Assistance Systems (ADAS).
The ADAS systems are grouped into two categories:

- Advisory (Warning) Systems
- Intervention Systems

Advisory Systems

These system trigger lights, LCD messages, sound and haptic responses to advise the driver of a calculated safety threat. Experts are now moving away from the term 'Warning' and instead using 'Advisory' as it more accurately defines the functions.
Advisory Systems include:

- Forward Collision Warning
- Lane Departure Warning
- Blind Spot Monitoring
- Parking Assistance
- Birdseye View
- Pedestrian Detection
- Traffic Sign Recognition
- Cross Traffic Alert

Intervention Systems

These systems encompass all of the aspects found in the Advisory Systems with the additional feature of controlling the vehicle. All systems offer an override option, this can be done by switching a particular system or all systems OFF. Alternatively, if a vehicle intervenes incorrectly the action can be overridden by fighting against the intervention (for example: if the vehicle brakes without reason, a hard acceleration gesture will override the Control Module).
Intervention Systems include:

- Emergency Braking
- Collision Avoidance
- Lane Departure Intervention
- Blind Spot
- Adaptive (Intelligent) Cruise Control
- High Beam Assist
- Automatic Parking
- Pedestrian Protection System

All of these systems are gaining in popularity and moving closer by the day toward Automated Driverless Vehicles.

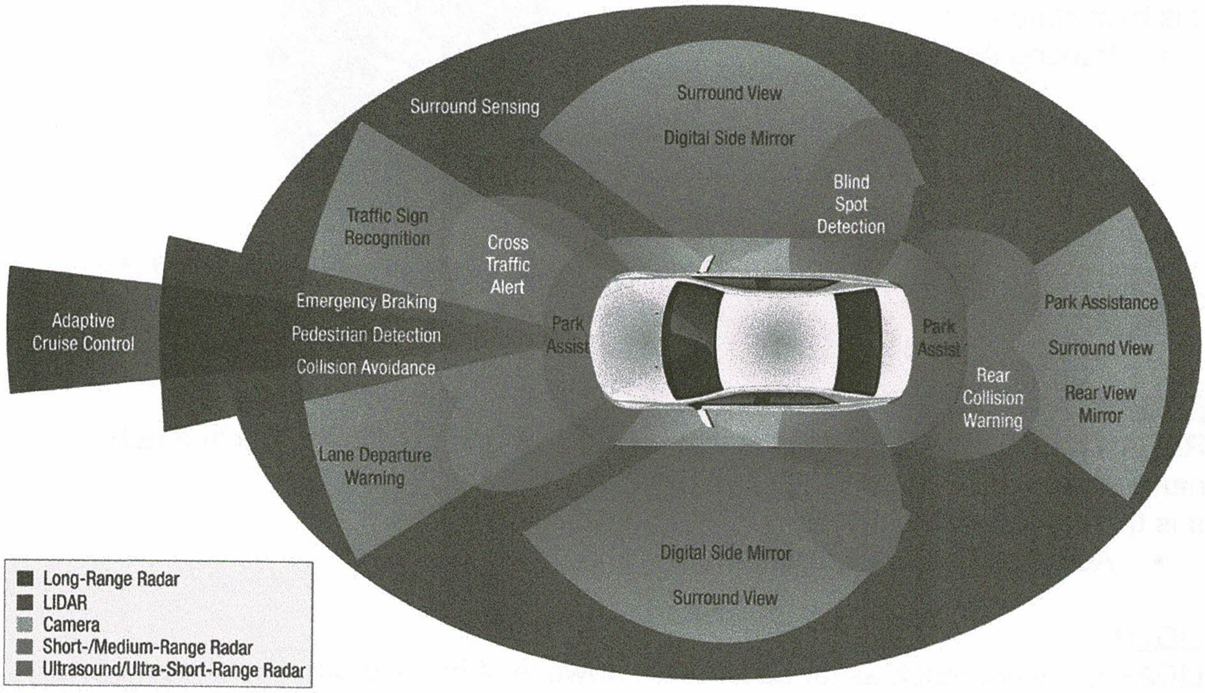
SENSORS

In order for these safety systems to work they need a series of sensors that are able to share their information with the other safety systems.

There is no one sensor that can provide all of the required input information (at least not yet), so these systems share information across the CAN Bus network to piece together a image of the surrounding area.

The sensors fall into two groups:

1. Echolocation
   - SONAR
   - RADAR
   - LIDAR
2. Vision
   - Camera
   - Stereo Camera
   - Infrared
   - Far Infrared Sensor


Adaptive Cruise Control
Surround Sensing
Traffic Sign Recognition
Cross Traffic Alert
Emergency Braking
Pedestrian Detection
Collision Avoidance
Lane Departure Warning
Park Assis
Surround View
Digital Side Mirror
Blind Spot Detection
Park Assist
Rear Collision Warning
Park Assistance
Surround View
Rear View Mirror
Digital Side Mirror
Surround View
■ Long-Range Radar
■ LIDAR
■ Camera
■ Short-/Medium-Range Radar
■ Ultrasound/Ultra-Short-Range Radar

Note:

Radar has become a noun and is recognised as a word. But it started out as and acronym RAdio Detection And Ranging.

Similarly, LIDAR stands for LIght Detection And Ranging. If a manufacturer states that it is using a laser sensor it is a LIDAR!

SENSORS continued...

Echolocation Sensors
All of these sensors work off the same principle, which is that if you send out a signal most hard surfaces will reflect that signal. The signal echo is calculated to draw an image of the surrounding objects as well as their speed in relation to the moving vehicle. The key advantage in these systems is that they monitor the environment by means of a signal that most humans do not posses.

- SONAR: SO(und) N(avigation) A(nd) R(anging)
- RADAR: RA(dio) D(etection) A(nd) R(anging)
- LIDAR: LI(ght) D(etection) A(nd) R(anging)

Each of these systems uses a different signal and each signal type has its pros and cons:

SONAR
SONAR provides a very wide angle but short range signal, vehicle SONAR Sensors are classified as 'Ultrasonic' which means they are in an extremely high frequency above the hearing range of Humans.

It is best suited for:

- Parking Assistance

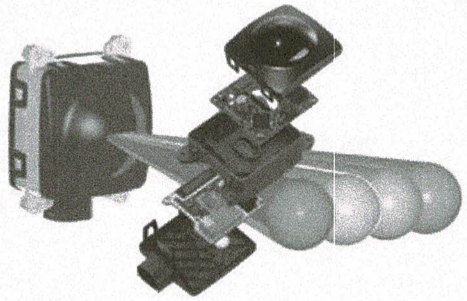
Note: *SONAR works very well under water but that is not of much use in a car!*

RADAR
RADAR provides the longest distance of sensing and measuring but in a rather narrow beams.
It is therefore best suited for:

- Adaptive Cruise Control

LIDAR
LIDAR does not reach as far as RADAR, however it has a broader range and it can be more successful in detecting objects that are not as hard and therefore do not reflect the radio wave. LIDAR's other advantage is speed, light travels faster than radio waves and sound waves.
It is best suited for:

- Emergency Braking
- Collision Avoidance



SENSORS continued...

Vision Sensors

Vision Sensors fall into two categories:

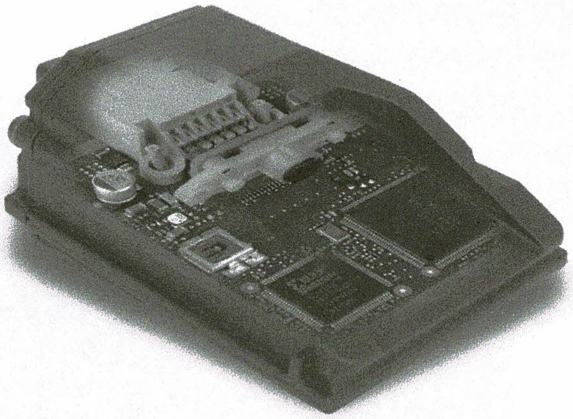
- Camera
- Infrared

Camera's

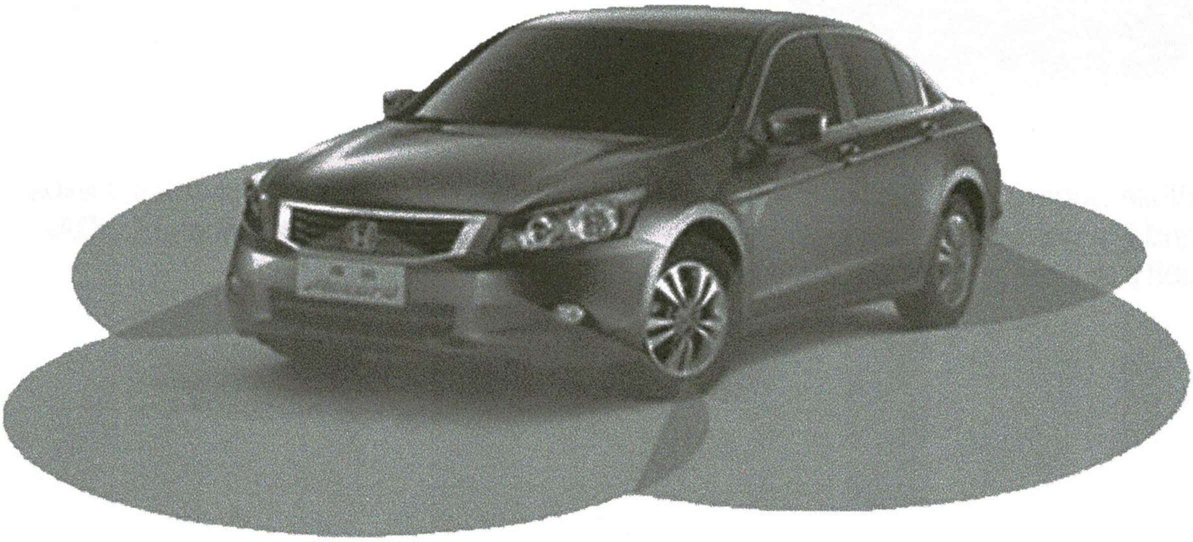
The one advantage that cameras have over Echolocation Systems in that the Control Module may be able identify what an object is and then send out the information for the ADAS systems to respond to, where Echolocation Systems can only identify that there is an object.

A Control Module is able to use a single camera to look for objects that it has been programmed to identify. It cannot measure how far away an object is or how fast it is moving (unless it is travelling at 90° to the camera).
Single camera's are best suited for:

- Lane Departure Intervention
- Traffic Sign Recognition
- Reversing Camera
- Birdseye View



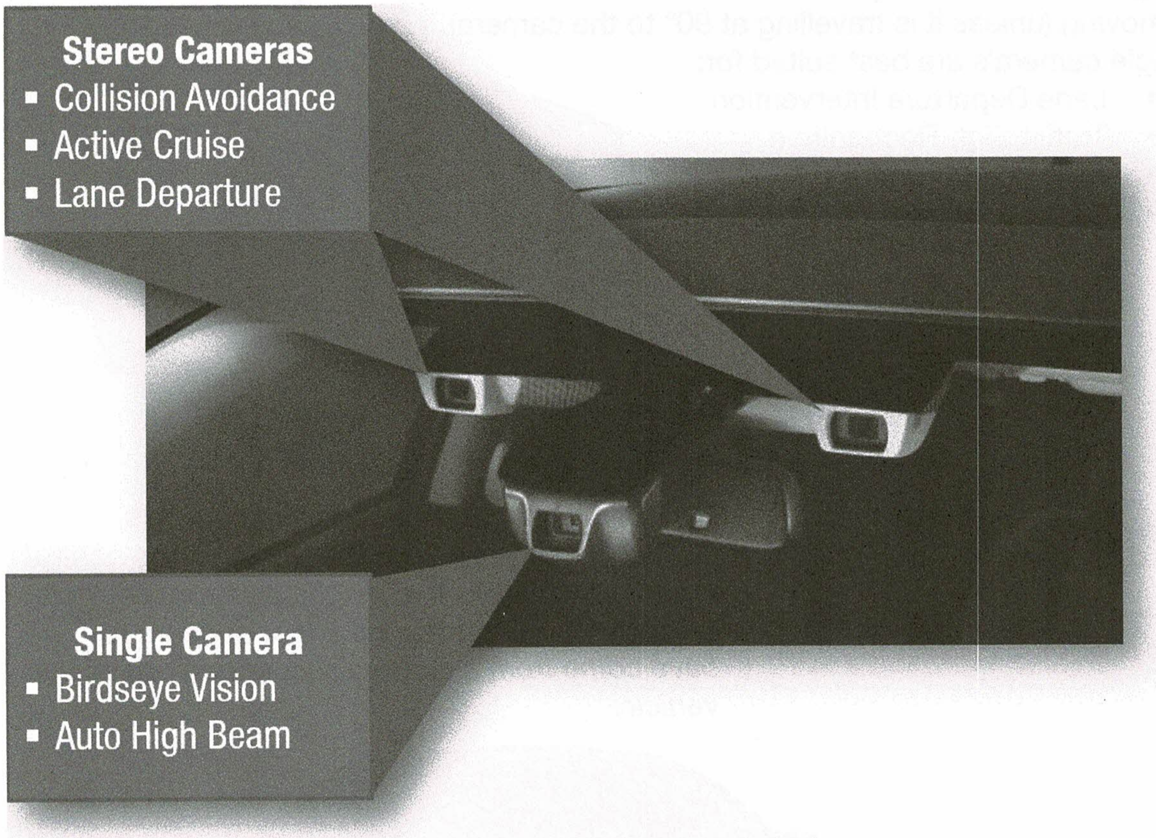
Note: *Birdseye View uses four wide angle single camera's located around the vehicle. The control module processes the images and applies angle corrections to create a view that appears to have come from a camera suspended above the vehicle!*



SENSORS continued...

Stereo Camera's simulate stereoscopic vision which allows the Control Module to calculate distance in the same way the human brain determines depth perception. Like single camera's the control module will try to identify how far away an object is, what direction it is moving, how fast it is moving in relation to the vehicle and also what the object is. The main downside of Stereo Camera's is they suffer from many of the same limitations as human vision, basically if we can't see (due to fog, smoke, sun glare, etc...) then the Stereo Camera's can't see either.
Stereo Camera's can be used for:

- Adaptive Cruise Control
- Emergency Braking
- Collision Avoidance
- Lane Departure Intervention


Stereo Cameras
▪ Collision Avoidance
▪ Active Cruise
▪ Lane Departure
Single Camera
▪ Birdseye Vision
▪ Auto High Beam

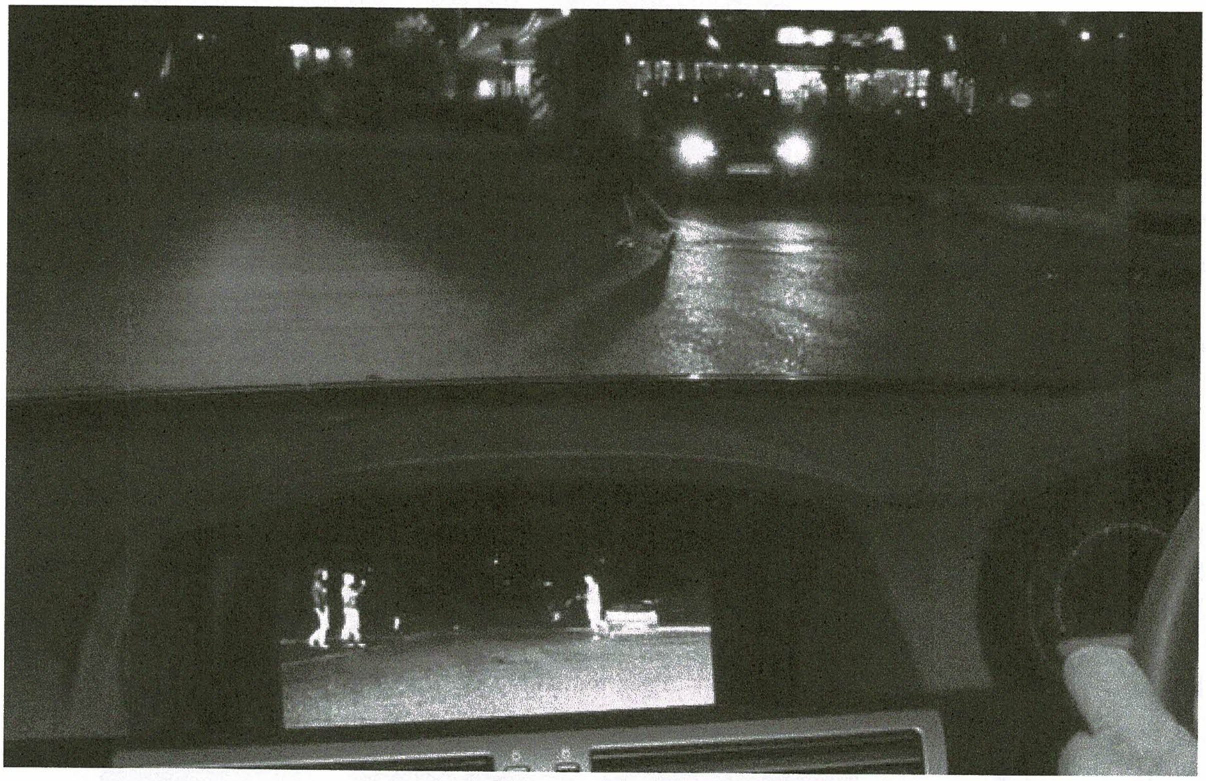
While Subaru uses Stereo Camera's for all of it's long distance calculations, Lexus and Mercedes Benz are combining Stereo Camera's with the assistance of LIDAR unit's to obtain class leading results.

SENSORS continued...

Infrared Sensors

Infrared Sensors are technically a type of camera, the wavelength of infrared light is just slightly out of human visual spectrum. Most thermal radiation emitted by objects below 50°C is in the form of infrared radiation. So by tuning a camera to look for infrared radiation a picture can be generated that is not visible to the human eye, this is sometimes called "Night Vision"

Infrared camera's play an important role in pedestrian detection because humans like all animals emit infrared radiation.

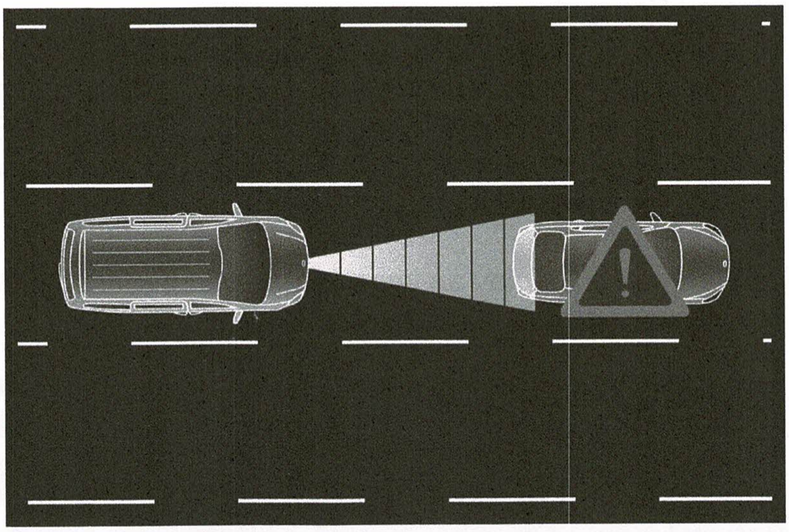


A BMW with Infrared Camera, there are 3 pedestrians in front and only one pair of shoes is visible

FEEDBACK

Visual

- Warning Lights
- LCD Graphics
- Head Up Display



Visual warnings provide the driver with feedback, however if the driver is distracted and/or drowsy they may not notice the visual cues.

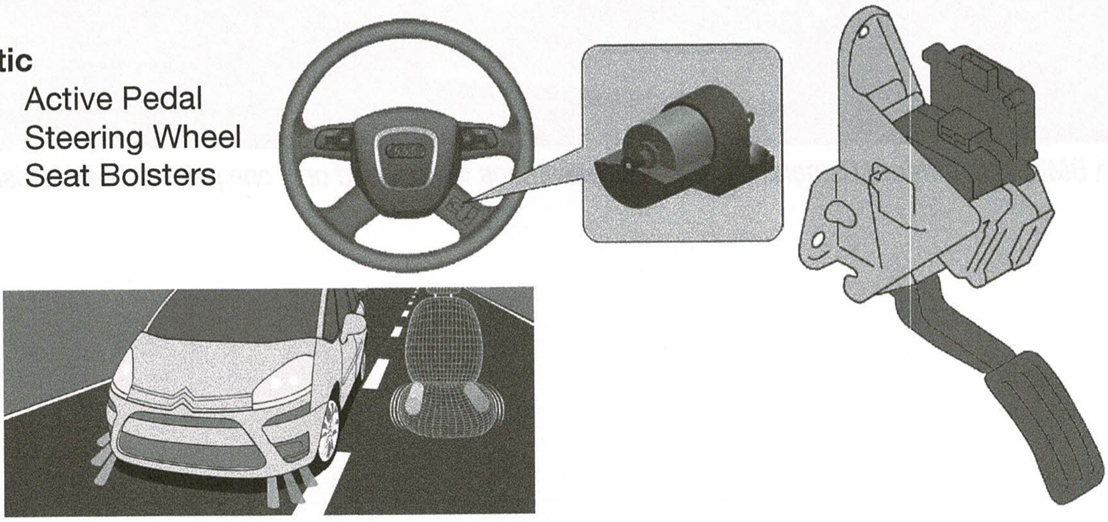
Audible

- Simulated
- Chime

Audible warnings may be more noticeable, they can be either a basic chime or the can simulate road noise. An example is, that some Lane Departure Warning Systems will simulate the sound of running over rumble strips if you veer from your lane.

Haptic

- Active Pedal
- Steering Wheel
- Seat Bolsters



Haptic feedback is the most effective, some cars will shake the steering wheel, some simulate the sensation of driving over rumble strips through the seat bolsters. The Y62 Nissan Patrol is fitted with an Active Accelerator Pedal that pushes back against the drivers foot whenever the Active Cruise Control or Frontal Collision System is activated.

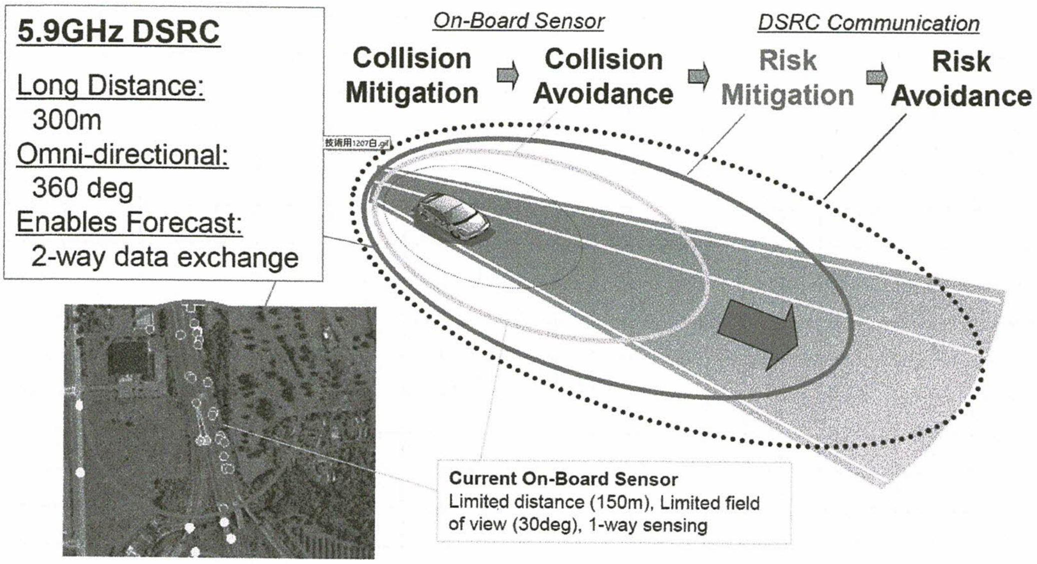
FUTURE SYSTEMS

V2×

The next step toward Driveless Cars is a technology coined V2×.
V2× incorporates two technologies:

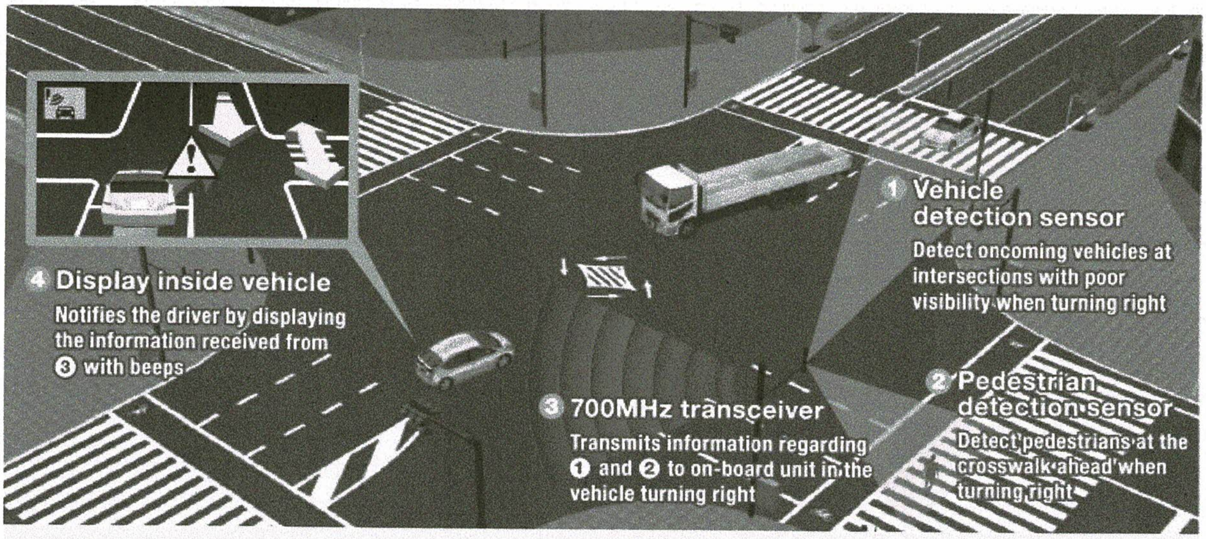
- Vehicle to Vehicle (V2V)
- Vehicle to Infrastructure (V2I)

V2V systems communicate with all other V2V vehicles within a 300m range. All vehicle share their data about direction, speed and intention (is the indicator on).


5.9GHz DSRC
Long Distance:
300m
Omni-directional:
360 deg
Enables Forecast:
2-way data exchange
On-Board Sensor
DSRC Communication
Collision Mitigation
Collision Avoidance
Risk Mitigation
Risk Avoidance
技術用1207B.gif
Current On-Board Sensor
Limited distance (150m), Limited field of view (30deg), 1-way sensing

V2I systems communicate with the infrastructure. Particularly at intersections V2I can adjust stop light operation, warn the driver about possible pedestrians.

Vehicle-to-Infrastructure Communication


④ Display inside vehicle
Notifies the driver by displaying the information received from ③ with beeps
① Vehicle detection sensor
Detect oncoming vehicles at intersections with poor visibility when turning right
② Pedestrian detection sensor
Detect pedestrians at the crosswalk ahead when turning right
③ 700MHz transceiver
Transmits information regarding ❶ and ❷ to on-board unit in the vehicle turning right

Right-turn collision prevention system (❶❸❹)
Crossing pedestrian recognition enhancement system (❷❸❹)
This service uses roadside infrastructure to detect in real time and notify the driver of oncoming vehicles and pedestrians at the crosswalk ahead when turning right.

NOTES